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STREAK DAMPING

S-CUBED
A Division of Maxwell Laboratories, Inc.
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December 1989

Technical Report

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This report documents a study aimed at improving the damping in STREAK. We recommend a form and value for an artificial viscosity which appears to control ringing and overshoots without overdamping.

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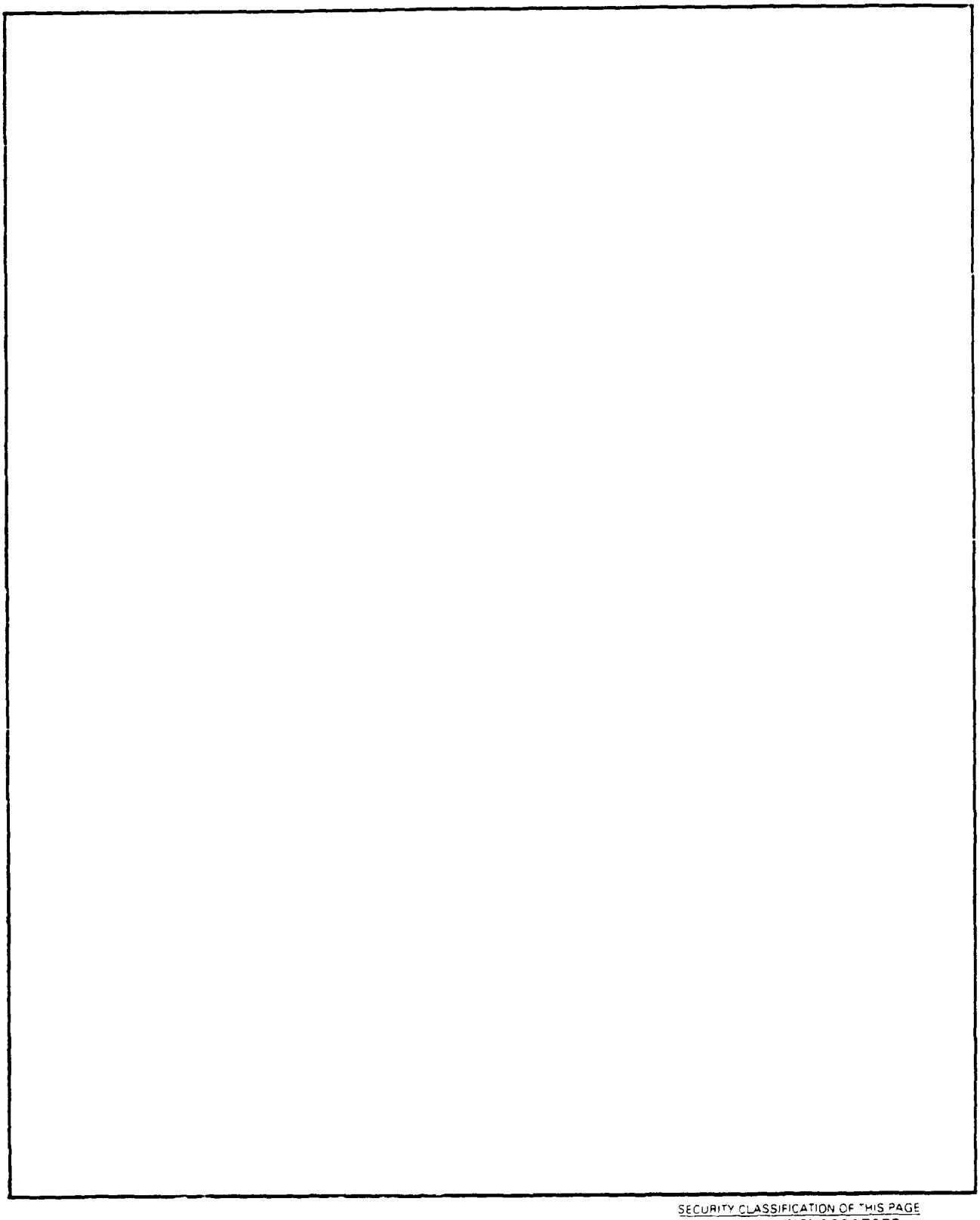

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY → TO GET	BY	TO GET ← DIVIDE
angstrom	1 000 000 X E -10	meters (m)
atmosphere (normal)	1 013 25 X E +2	kilo pascal (kPa)
bar	1 000 000 X E +2	kilo pascal (kPa)
barn	1 000 000 X E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1 054 350 X E +3	joule (J)
calorie (thermochemical)	4 184 000	joule (J)
cal (thermochemical)/cm^2	4 184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3 700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1 745 329 X E -2	radian (rad)
degree Fahrenheit	$t_c = (t°f + 459\ 67)/1\ 8$	degree kelvin (K)
electron volt	1 602 19 X E -19	joule (J)
erg	1 000 000 X E -7	joule (J)
erg/second	1 000 000 X E -7	watt (W)
foot	3 048 000 X E -1	meter (m)
foot-pound-force	1 355 818	joule (J)
gallon (U.S. liquid)	3 785 412 X E -3	meter^3 (m^3)
inch	2 540 000 X E -2	meter (m)
jerk	1 000 000 X E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1 000 000	Gray (Gy)
kilotons	4 183	terajoules
kip (1000 lbf)	4 448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6 894 757 X E +3	kilo pascal (kPa)
ktap	1 000 000 X E +2	newton-second/m^2 (N-s/m^2)
micron	1 000 000 X E -6	meter (m)
mil	2 540 000 X E -5	meter (m)
mile (international)	1 609 344 X E +3	meter (m)
ounce	2 834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4 448 222	newton (N)
pound-force inch	1 129 948 X E -1	newton-meter (N-m)
pound-force/inch	1 751 268 X E +2	newton/meter (N/m)
pound-force/foot^2	4 788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6 894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4 535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4 214 011 X E -2	kilogram-meter^2 (kg-m^2)
pound-mass/foot^3	1 601 846 X E +1	kilogram/meter^3 (kg/m^3)
rad (radiation dose absorbed)	1 000 000 X E -2	**Gray (Gy)
roentgen	2 579 760 X E -4	coulomb/kilogram (C/kg)
shake	1 000 000 X E -8	second (s)
slug	1 459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1 333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity, 1 Bq = 1 event/s
**The Gray (Gy) is the SI unit of absorbed radiation

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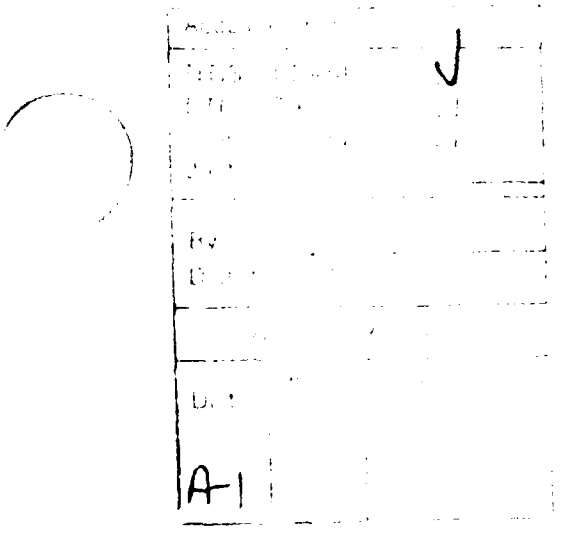


SECTION 1
TECHNICAL DISCUSSION

While running the S-CUBED final prediction for MISTY ECHO, it was noted that the on-axis profiles appeared to be ringing at and behind the front. This manifested itself in the monitor plots, as well, with noticeable ringing. Following the conclusion of the prediction calculation, we undertook a numerical study aimed at improving the damping in STREAK. This report documents that study.

The need for a certain amount of damping in finite difference solutions of stress wave propagation has long been recognized. It is also generally understood that this damping may be explicit, as in the Richtmeyer-von Neumann artificial viscosity, or inherent in the finite difference approximations as truncation error, as is the case in the Eulerian first order donor scheme.

The need for damping (code glue, to some) is somewhat disturbing, but can be shown to have both physical and mathematical justifications. The case of shock propagation is where the need for damping is most clear. Since real viscous effects are important for the structure of physical shocks, it should not be surprising that a numerical analogue of viscosity is required for numerical simulation of a shock. There is, however, a much more profound explanation. If we assume a steady wave with a constant profile, it can be shown that the physical loading path of a Lagrangian particle is along a Rayleigh line. (This is not widely appreciated, but it is true.) The terminal state of this loading is the Rankine-Hugoniot state, an equilibrium state, but other states on the loading path are non-equilibrium states which are not compatible with the equation of state. In other words, the material states required by the dynamics of shock wave propagation are not consistent with the equation of state. In addition, unless there are non-equilibrium contributions to the pressure which can make the material pressure compatible with the dynamics, there will not be a mathematical solution to the steady wave problem. This, we believe, is the cause of numerical oscillation.

Thus in order to have well-behaved numerical solutions, it is essential to have viscous or other non-equilibrium stresses. Low order schemes produce these contributions by accident. High order schemes require an explicit treatment.

In the early 1980's STREAK was upgraded from a first order code with no explicit damping to a second order code in space and time with a FRAM-like damping.[1] This scheme looks for local oscillations and introduces damping as needed only to maintain monotonicity. The code was extensively tested and the FRAM method was found to perform well in a large number of test problems. However, recent production calculations with STREAK have exhibited undesirable spikes and ringing which have been traced to insufficient damping at the wavefront when the overall computational time step is much smaller than the Courant time step at the shock front. This will occur when there are regions of the problem which require a more stringent time step than that carried at the shock front. This often happens in a calculation which carries both the fireball and the stress wave in the ground.

This has led us to consider the inclusion of additional explicit damping. Some care is required because of the potential for a destructive interaction with existing damping mechanisms. To prevent overdamping, certain terms in the finite difference equations were recentered to eliminate damping which was present for time steps near the Courant limit. There was no modification of the FRAM scheme which provides adequate damping when certain monotonicity conditions are not satisfied.

We then considered various combinations of linear and quadratic artificial viscosities. This exercise showed that linear artificial viscosity was required to control the numerical pathologies, but that quadratic viscosity had either small or negative effects on the solution. It appears that FRAM is adequately dealing with the problems that would otherwise require quadratic viscosity, and that additional quadratic viscosity provides too much damping. However, it appears that linear artificial viscosity is complementary to FRAM, and provides required damping where FRAM is inadequate. This is believed to be in the very stiff regime of the equation state, where the pressure is comparable or small compared to the bulk modulus.

---

1. Chapman, M., "FRAM-Nonlinear Damping Algorithms for the Continuity Equation," J. Comp. Phys. 44. 84-103, 1981.

The form of the viscosity used is as follows:

$$Q = - \rho C_L C_s \Delta\text{-}v \text{ , for all } \Delta\text{-}v$$

where

ρ = material density

C_L = damping coefficient

C_s = local sound speed

Δ-v = velocity difference

We tried various values of the damping coefficient (C_L), and have found that a value of 0.5 is the best compromise between controlling the damping and minimal smearing and spreading of the wave.

Appendices A-D which follow compare four calculations which clearly demonstrate the merit of explicit linear artificial viscosity in addition to FRAM. The calculations model 1-D spherical explosions in MISTY ECHO grout with a starting pressure of 100 Mbar. The test matrix consists of coarse and fine Eulerian grids, with and without the code modification. The coarse grid simulates the zoning actually used for the Misty Echo calculation, while the fine grid solutions are essentially fully converged.

Appendix A	Standard STREAK	Coarse zoning
Appendix B	Standard STREAK	Fine zoning
Appendix C	STREAK with C = 0.5	Fine zoning
Appendix D	STREAK with C = 0.5	Coarse zoning

The coarse solution without the code modification produces waveforms which are quite noisy, and clearly questionable. The corresponding fine solution is clearly better behaved, with only a minor artifact at the wavefront. It is generally unambiguous how to interpret the fine zoned calculation.

With the modified code, the fine zoned calculation with the modified code is essentially identical to the fine zoned calculation with the unmodified code with the exception that overshoots at the wavefront are well controlled. The coarse calculation with the modified code gives quite good agreement with the fine zoned calculations, with only a minor overshoot at the wavefront. The improvement over the coarse calculation with the unmodified code is dramatic.

In spite of these results, linear artificial viscosity must be used with caution. There are reports of serious solution errors traceable to linear artificial viscosity. Two such cases that other at S-CUBED have had direct experience with are with the propagation of weak gasdynamic signals, and the propagation of linear elastic signals in Lagrangian codes. It is possible that these difficulties are unique to Lagrangian codes.

To test the gasdynamic question, we have performed a similar set of test calculations for a shock propagating in real air. For the high pressure regime (shock pressures greater than a few hundred bars), the linear artificial viscosity is still an improvement, albeit a small one. For the weak shock case (shock pressures down to 1.2 bars), the viscosity is a larger improvement and clearly a good feature to add to the code. The following appendices show the results.

Appendix E	Standard STREAK	High pressure	Fine zoning
Appendix F	STREAK with C = 0.5	High pressure	Fine zoning
Appendix G	Standard STREAK	Low pressure	Coarse zoning
Appendix H	Standard STREAK	Low pressure	Fine zoning
Appendix I	STREAK with C = 0.5	Low pressure	Fine zoning
Appendix J	STREAK with C = 0.5	Low pressure	Coarse zoning

In all these cases, the version with an artificial viscosity clearly improves the solution, and brings it close to what the standard, fine zoned case would suggest when the obvious over-ring is removed.

Even with these results, however, we think that the modified code should be used with caution until further studies can be completed. We need to run a two-dimensional test and this will be a rerun of part of the MISTY ECHO calculation to see if the problems clean up and be sure there are no unforeseen problems.

There remains the problem of filtering numerical oscillations out of existing solutions. The biggest difficulty here is estimating the true peak when there has been a numerical overshoot. We have taken two independent approaches to this problem, and have found the results to be consistent.

The first approach is based on the fact that the observed peaks (pressure, density and velocity) satisfy the equation of state Rankine-Hugoniot relations, but with a shock speed which is systematically different than the wave speed in the calculation. If we postulate that the calculational wave speed is correct and infer peak values from the equation of state Rankine-Hugoniot relations, these peak values appear reasonable in every case we examined. (The numerical wave speed is inherently noisy, and required smoothing.)

Figures 1 and 2 show the correction factors as a function of raw pressure and velocity for the S-CUBED MISTY ECHO final prediction.

As a check on this question, we ran a spherical 1D calculation with similar zoning and time steps as a proxy for the 2D problem. This calculation produced underdamped waveforms similar to those in the 2D calculations. We then performed a convergence analysis by refining the zones in the 1D problem. The results agree well with the corrected data as obtained by the procedure outlined above.

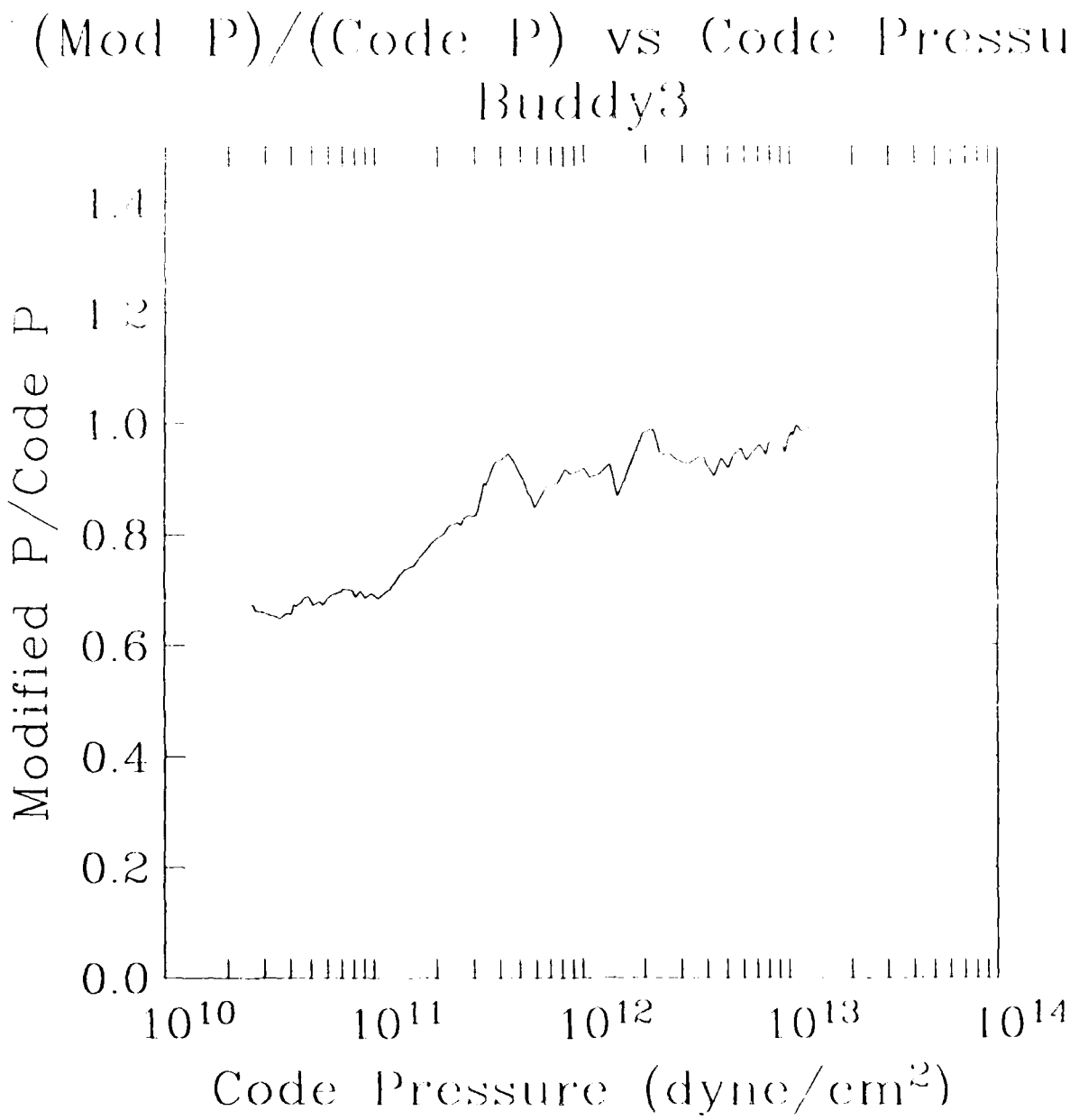


Figure 1 Corrected pressure/code pressure factor versus code pressure for BUDDY 3

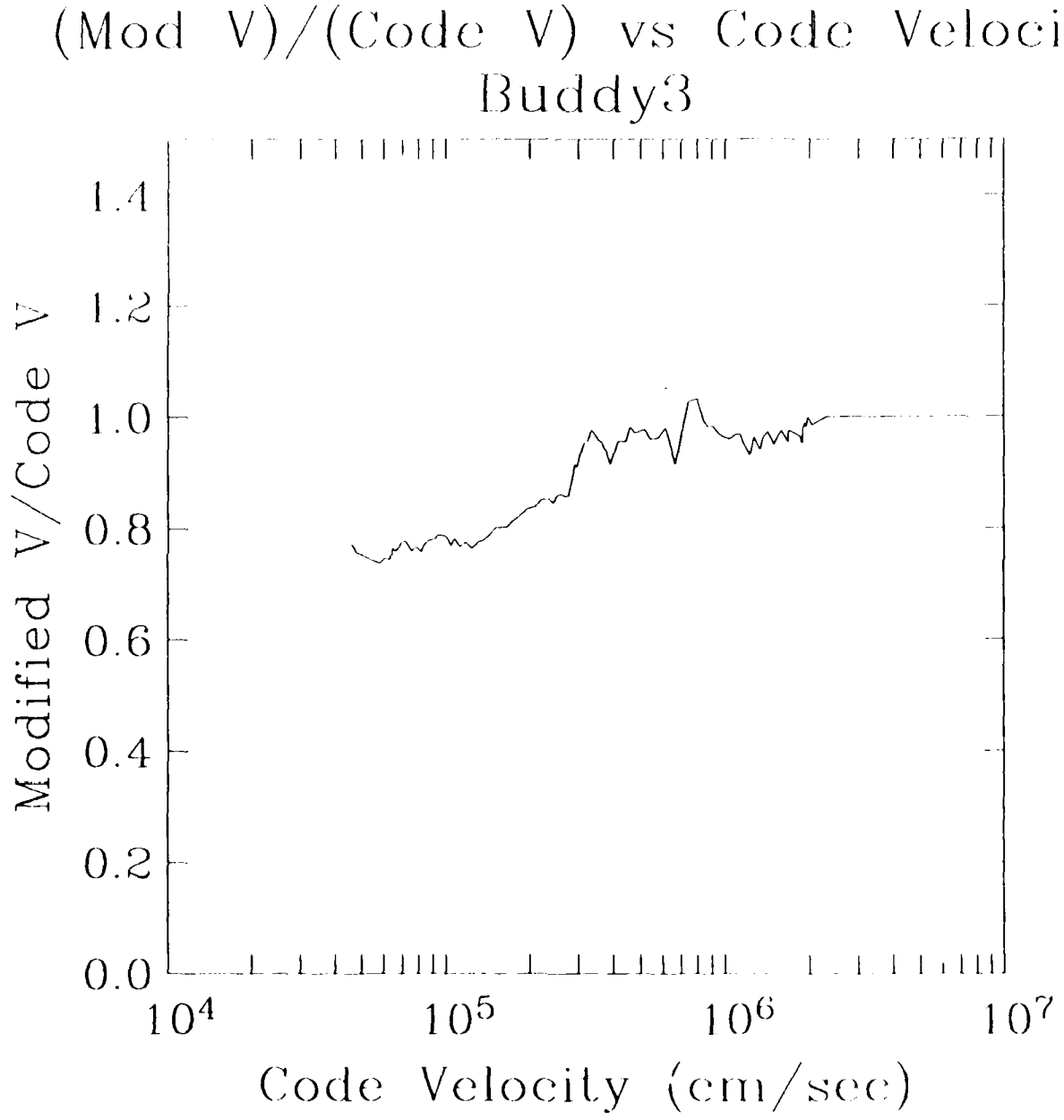
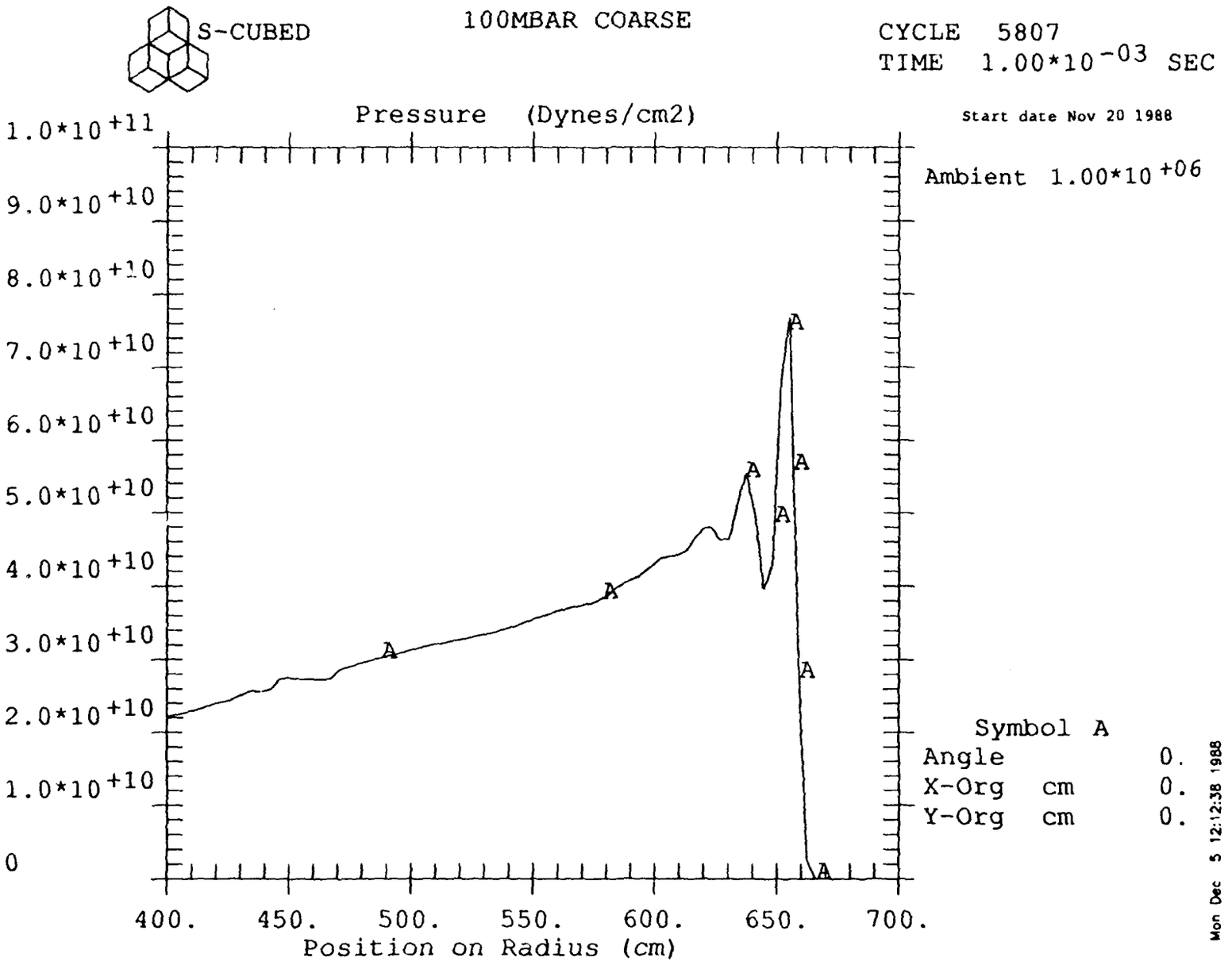


Figure 2. Corrected velocity/code velocity factor versus code velocity for BUDDY 3

APPENDIX A
STANDARD STREAK
COARSE ZONING


S-CUBED
100MBAR COARSE
CYCLE 5807
TIME 1.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Nov 20 1988
Ambient 1.00*10 +06
1.0*10 +11
9.0*10 +10
8.0*10 +10
7.0*10 +10
6.0*10 +10
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
400.
450.
500.
550.
600.
650.
700.
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Y-Org cm 0.
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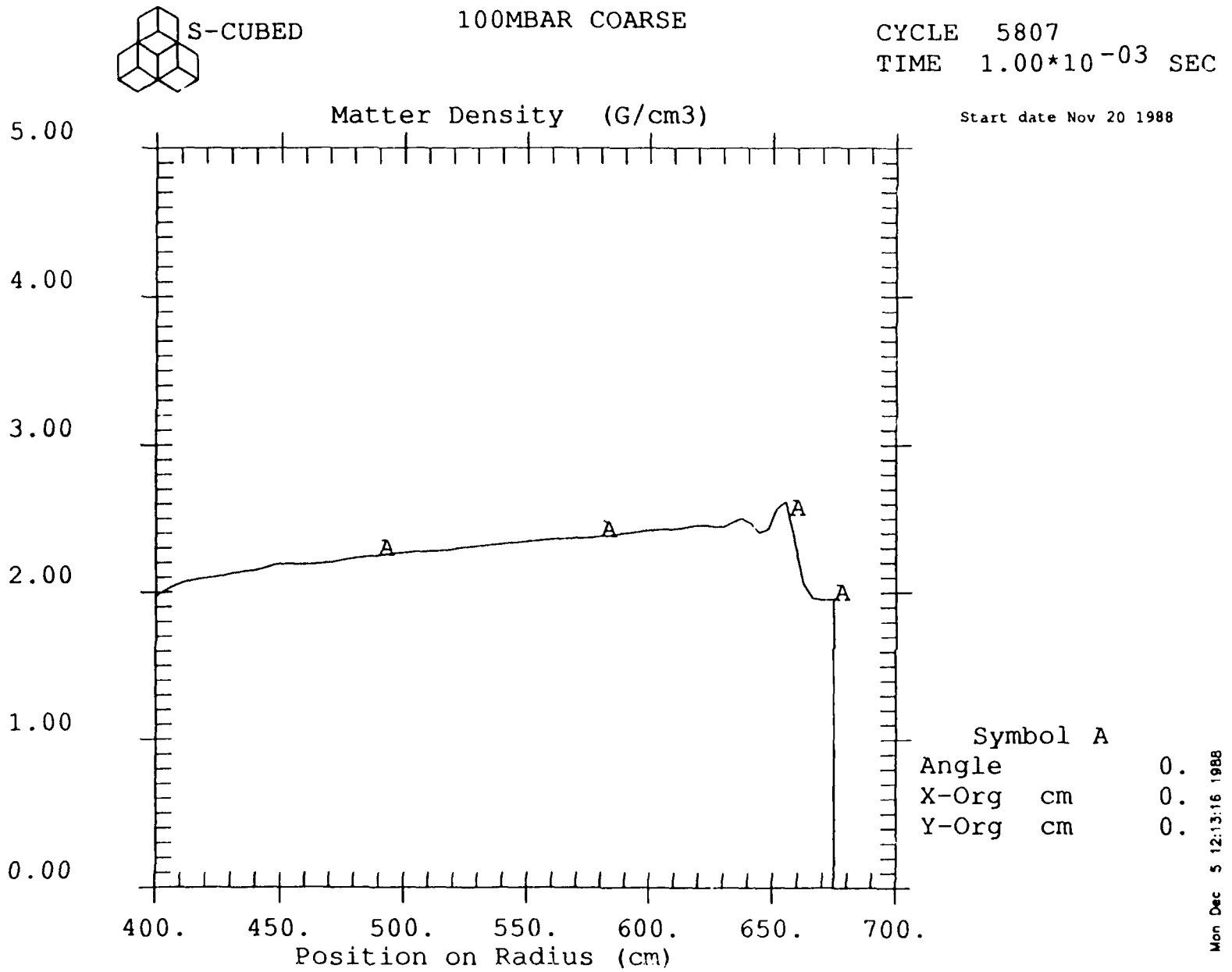
S-CUBED
100MBAR COARSE
CYCLE 5807
TIME 1.00*10^-03 SEC
Matter Density (G/cm3)
Start date Nov 20 1988
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4.00
3.00
2.00
1.00
0.00
400.
450.
500.
550.
600.
650.
700.
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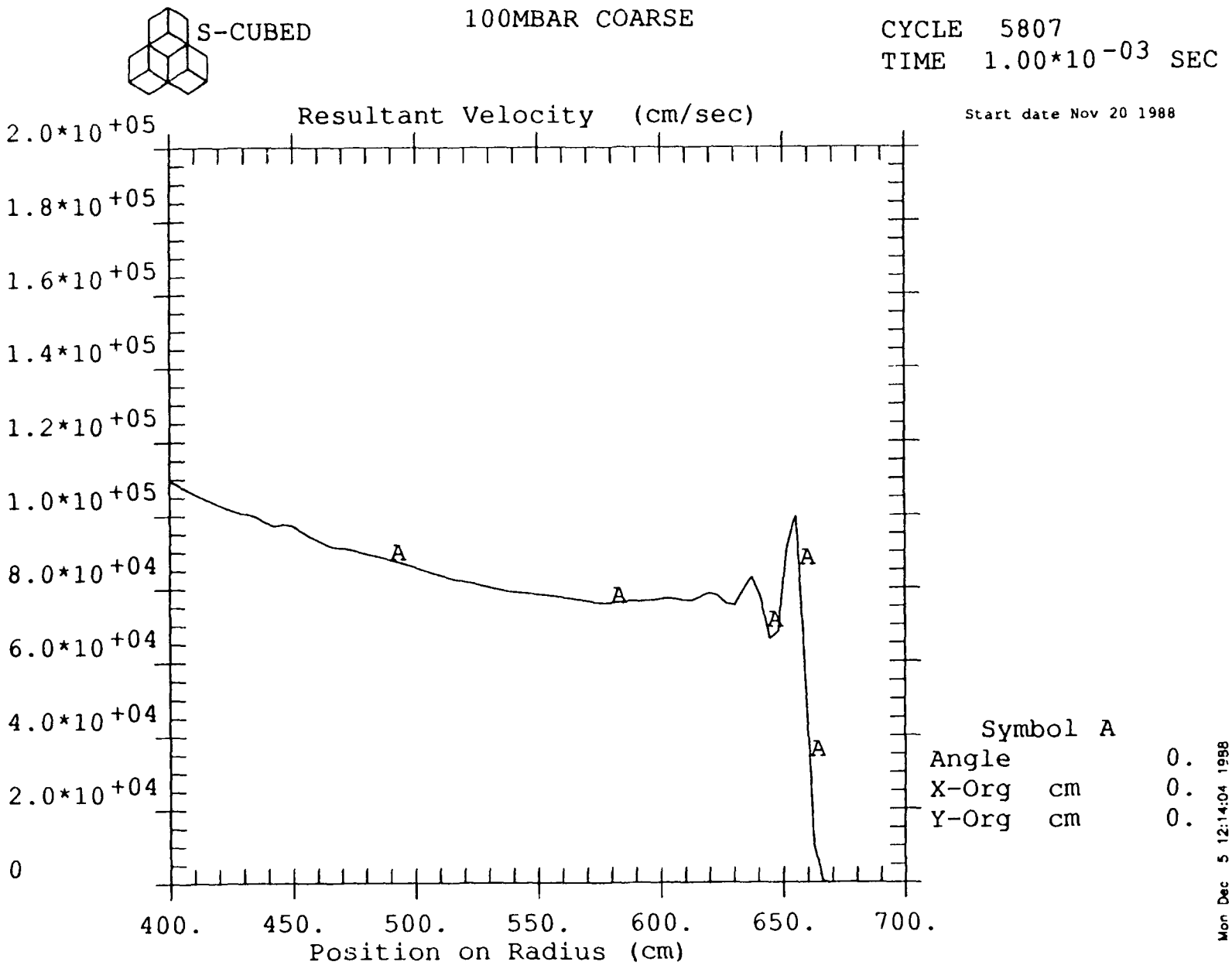
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100MBAR COARSE
CYCLE 5807
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Start date Nov 20 1988
Resultant Velocity (cm/sec)
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1.8*10+05
1.6*10+05
1.4*10+05
1.2*10+05
1.0*10+05
8.0*10+04
6.0*10+04
4.0*10+04
2.0*10+04
0
400.
450.
500.
550.
600.
650.
700.
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Y-Org cm 0.
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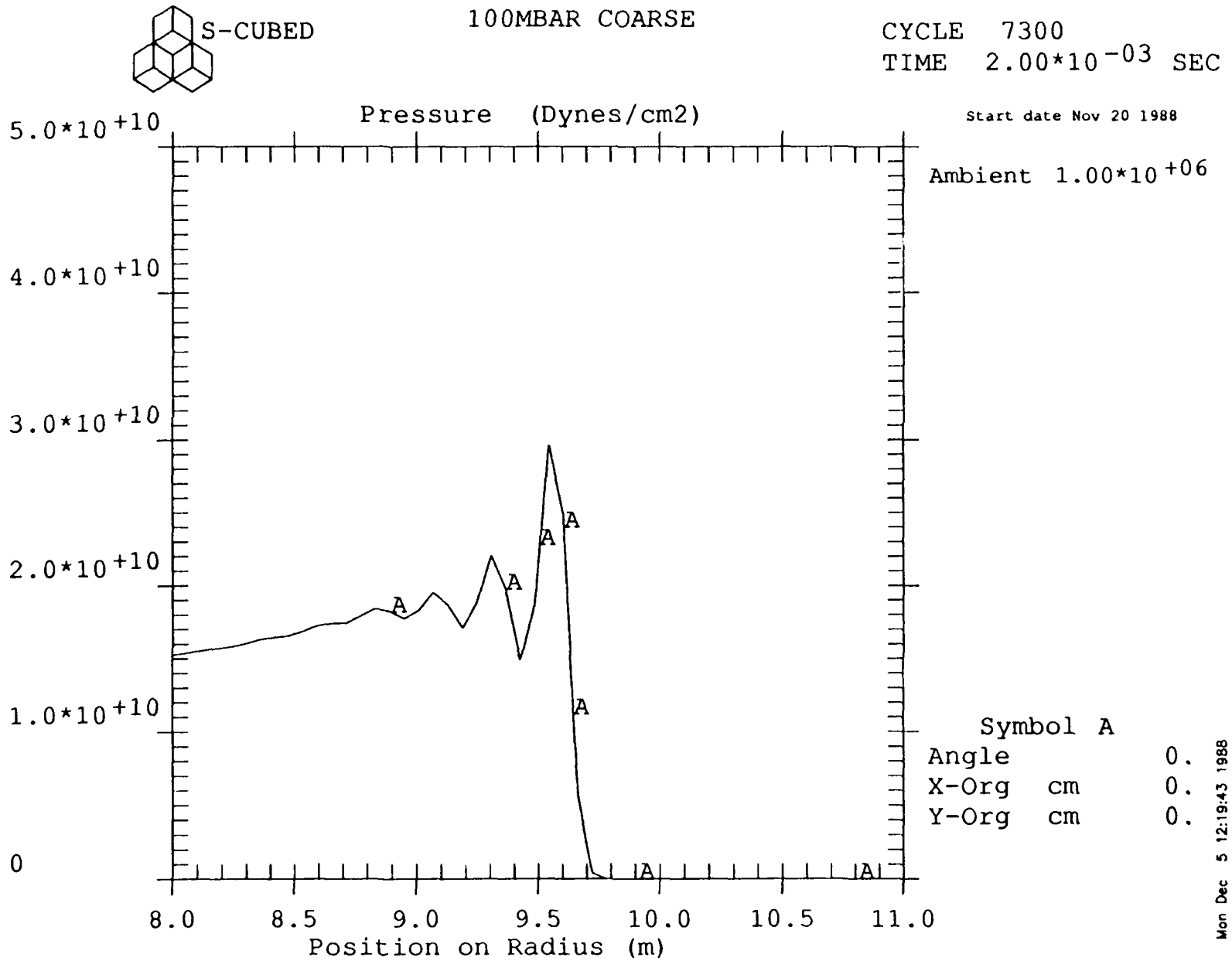
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100MBAR COARSE
CYCLE 7300
TIME 2.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Nov 20 1988
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5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
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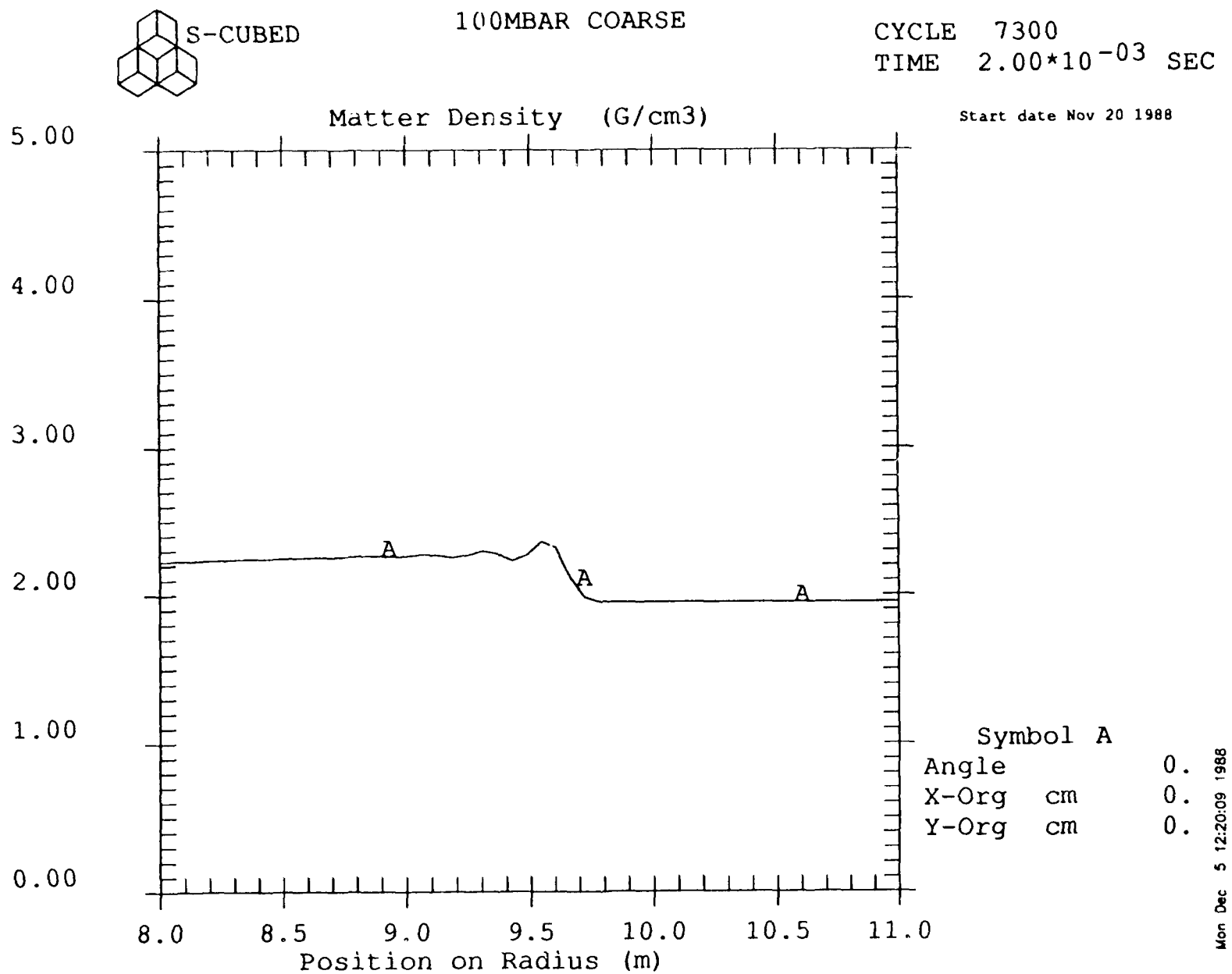
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100MBAR COARSE
CYCLE 7300
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Start date Nov 20 1988
Matter Density (G/cm3)
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4.00
3.00
2.00
1.00
0.00
A
A
A
8.0
8.5
9.0
9.5
10.0
10.5
11.0
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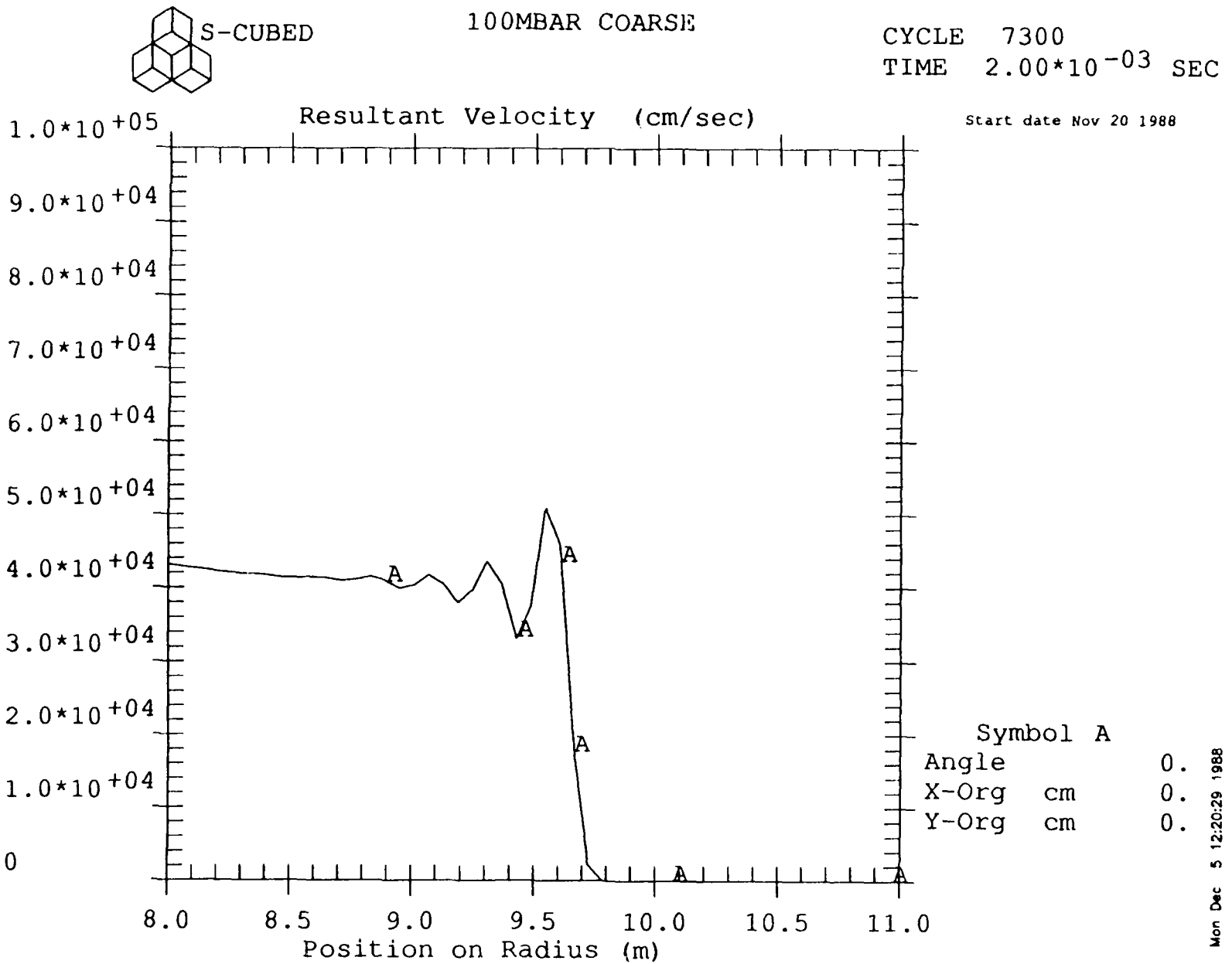
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100MBAR COARSE
CYCLE 7300
TIME 2.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Nov 20 1988
1.0*10+05
9.0*10+04
8.0*10+04
7.0*10+04
6.0*10+04
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
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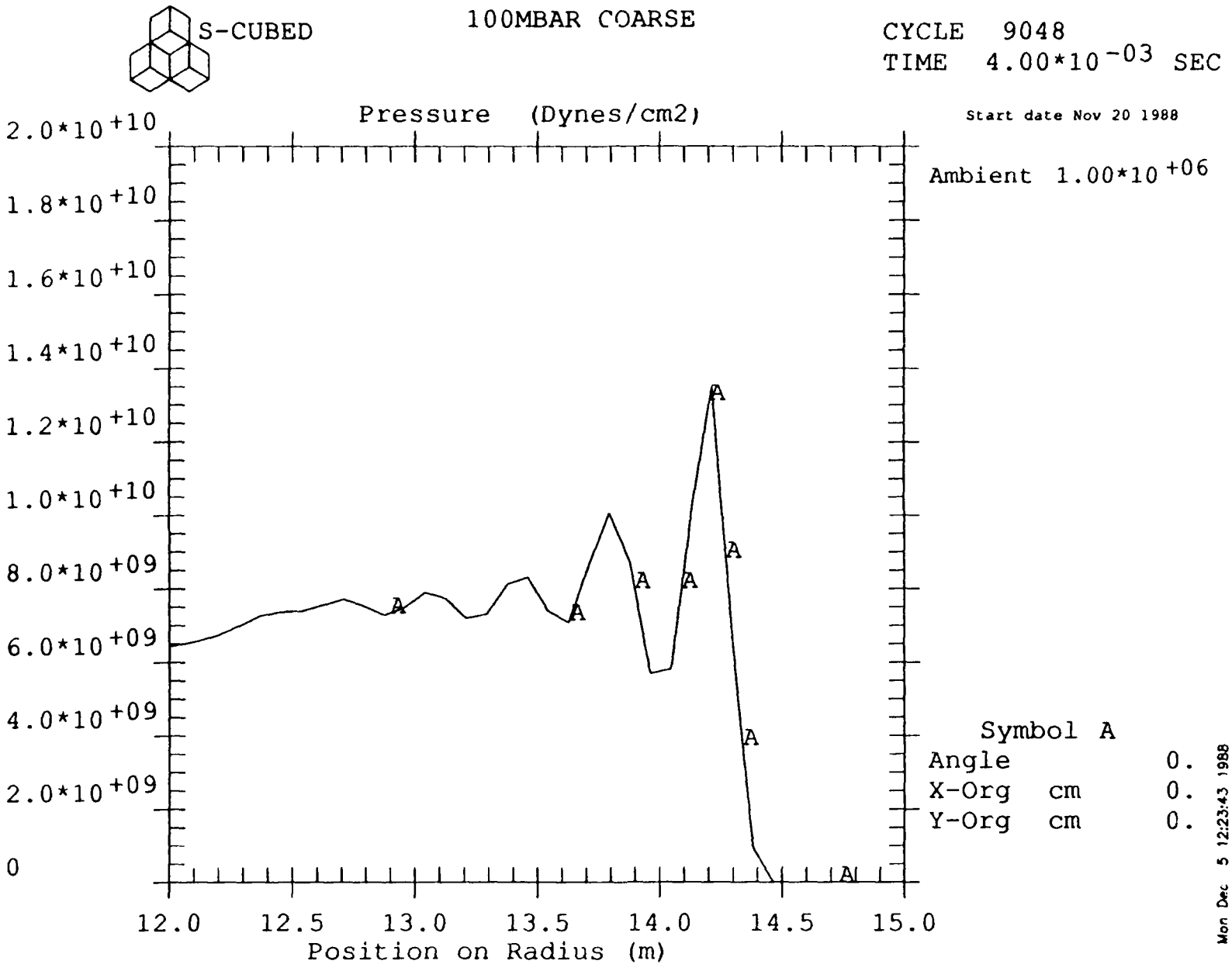
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Pressure (Dynes/cm2)
Start date Nov 20 1988
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1.6*10 +10
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1.2*10 +10
1.0*10 +10
8.0*10 +09
6.0*10 +09
4.0*10 +09
2.0*10 +09
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12.0
12.5
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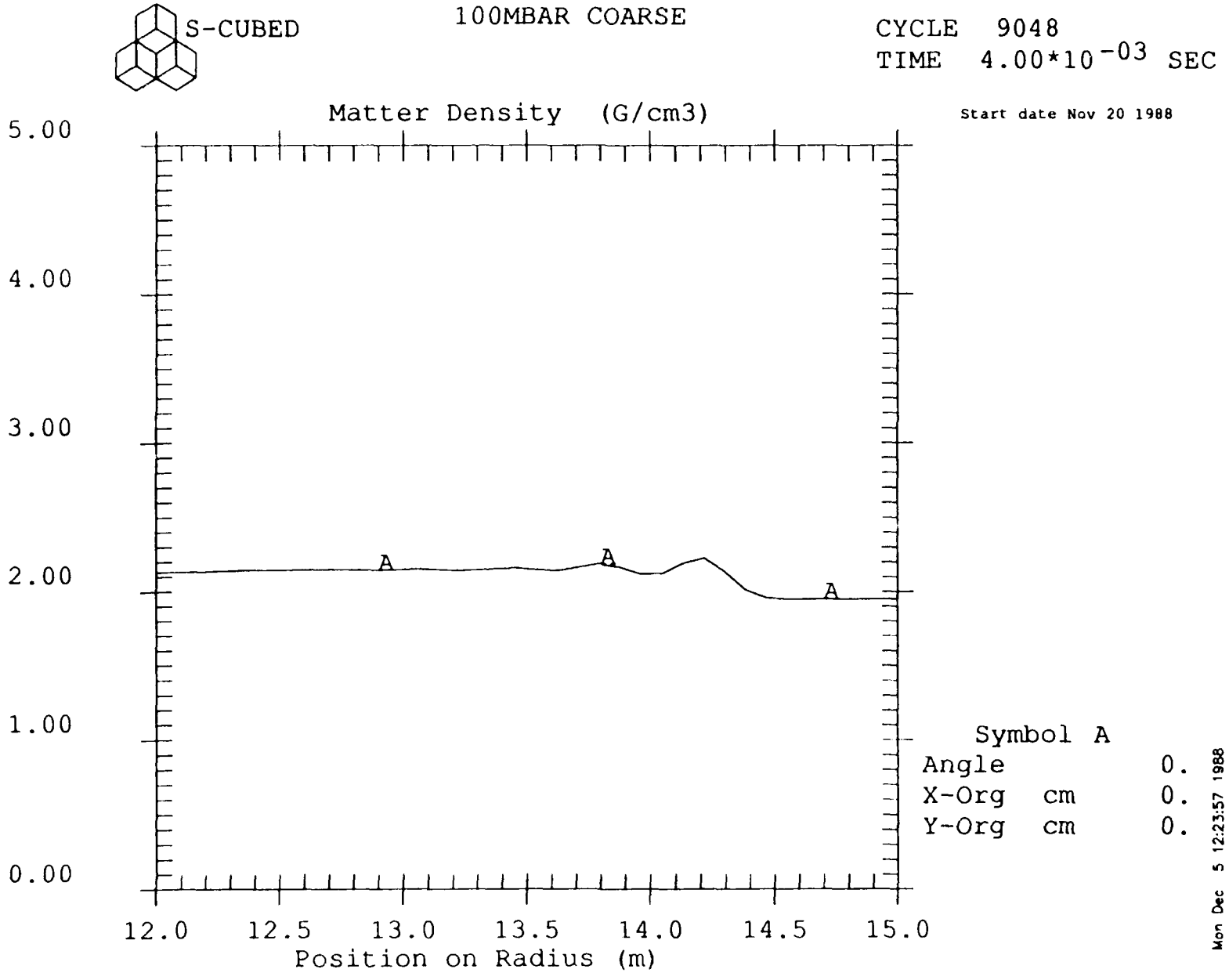
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Matter Density (G/cm3)
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3.00
2.00
1.00
0.00
A
A
A
12.0
12.5
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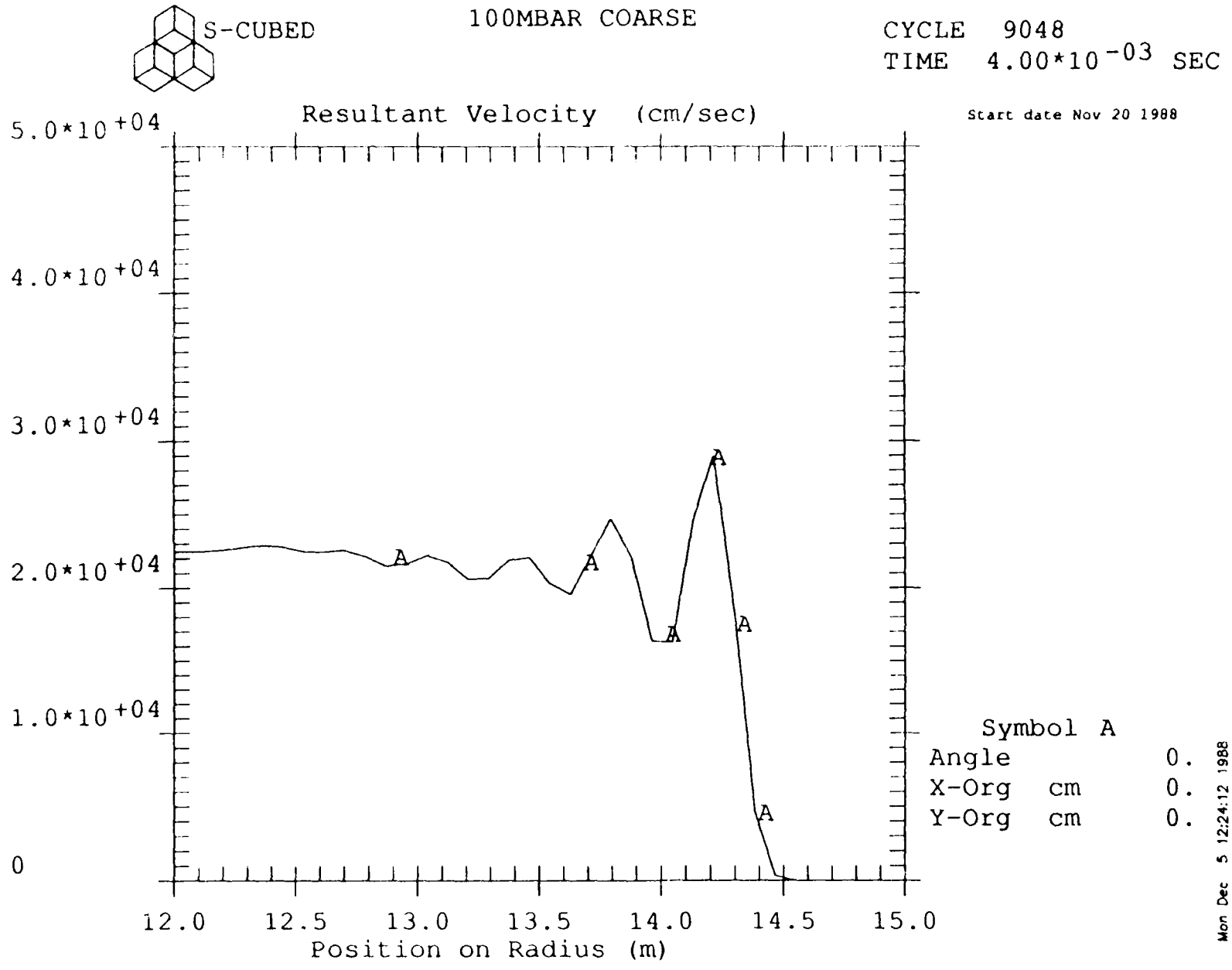
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1.0*10+04
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12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
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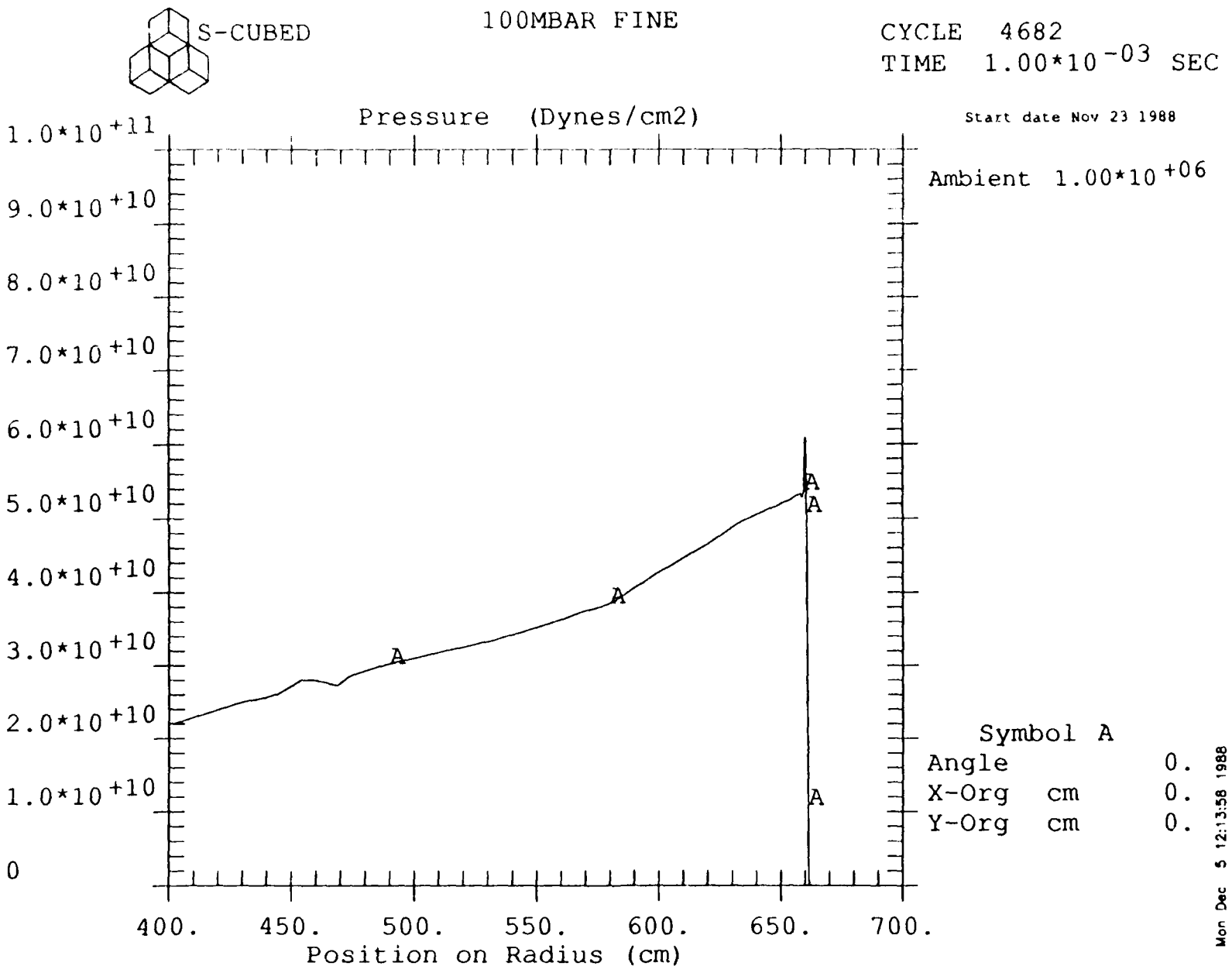
APPENDIX B
STANDARD STREAK
FINE ZONING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100MBAR FINE
CYCLE 4682
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Start date Nov 23 1988
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1.0*10 +11
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8.0*10 +10
7.0*10 +10
6.0*10 +10
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
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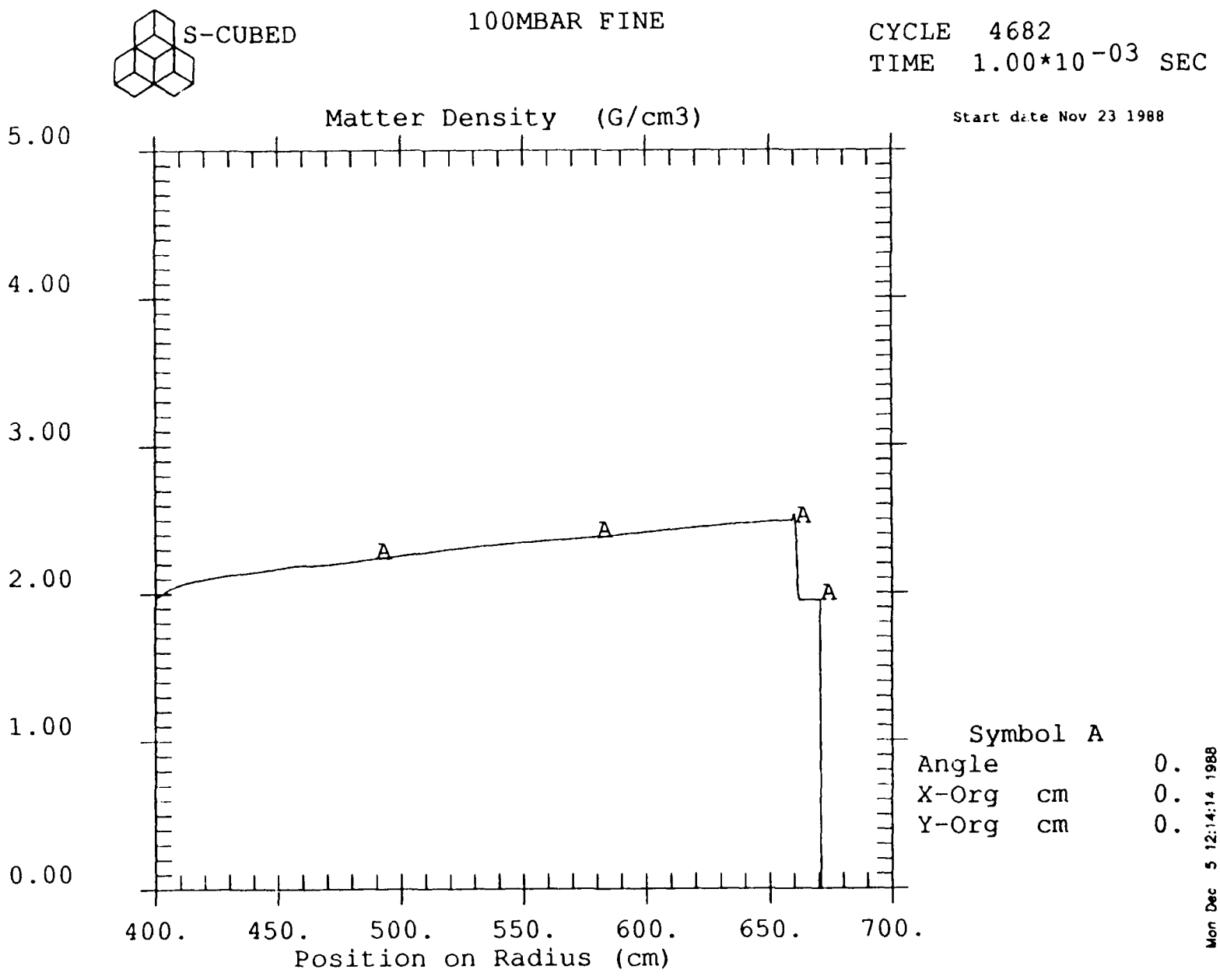
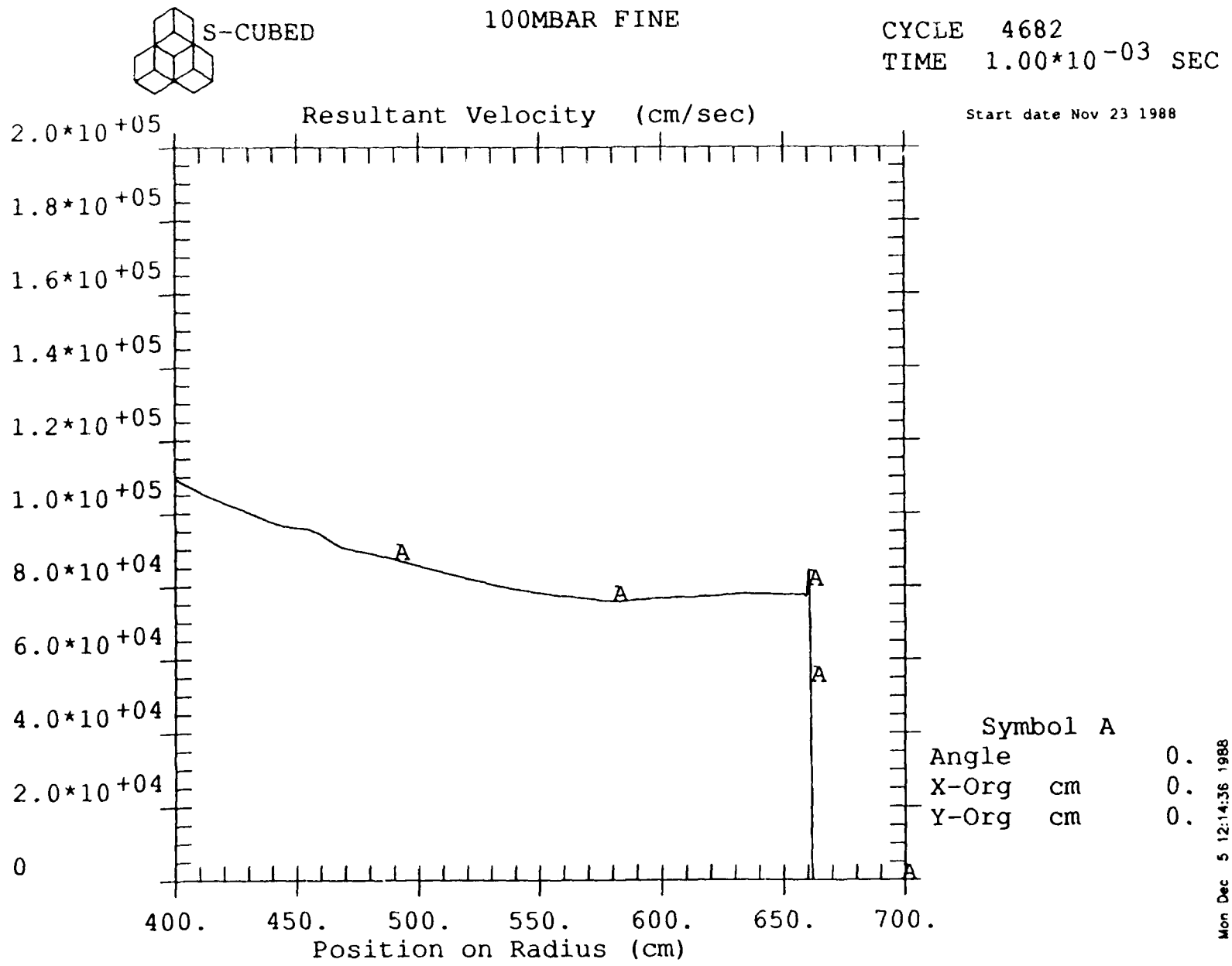
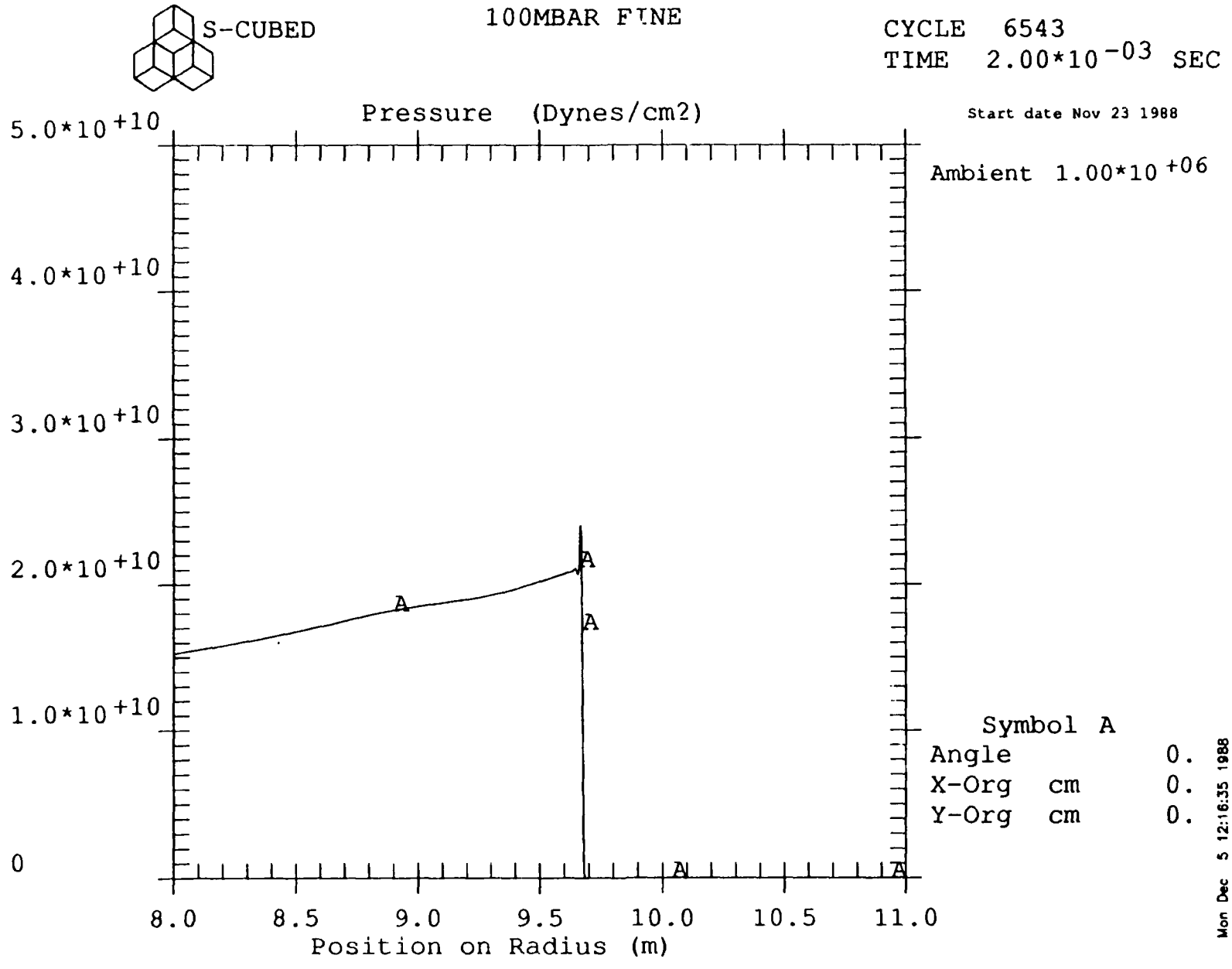
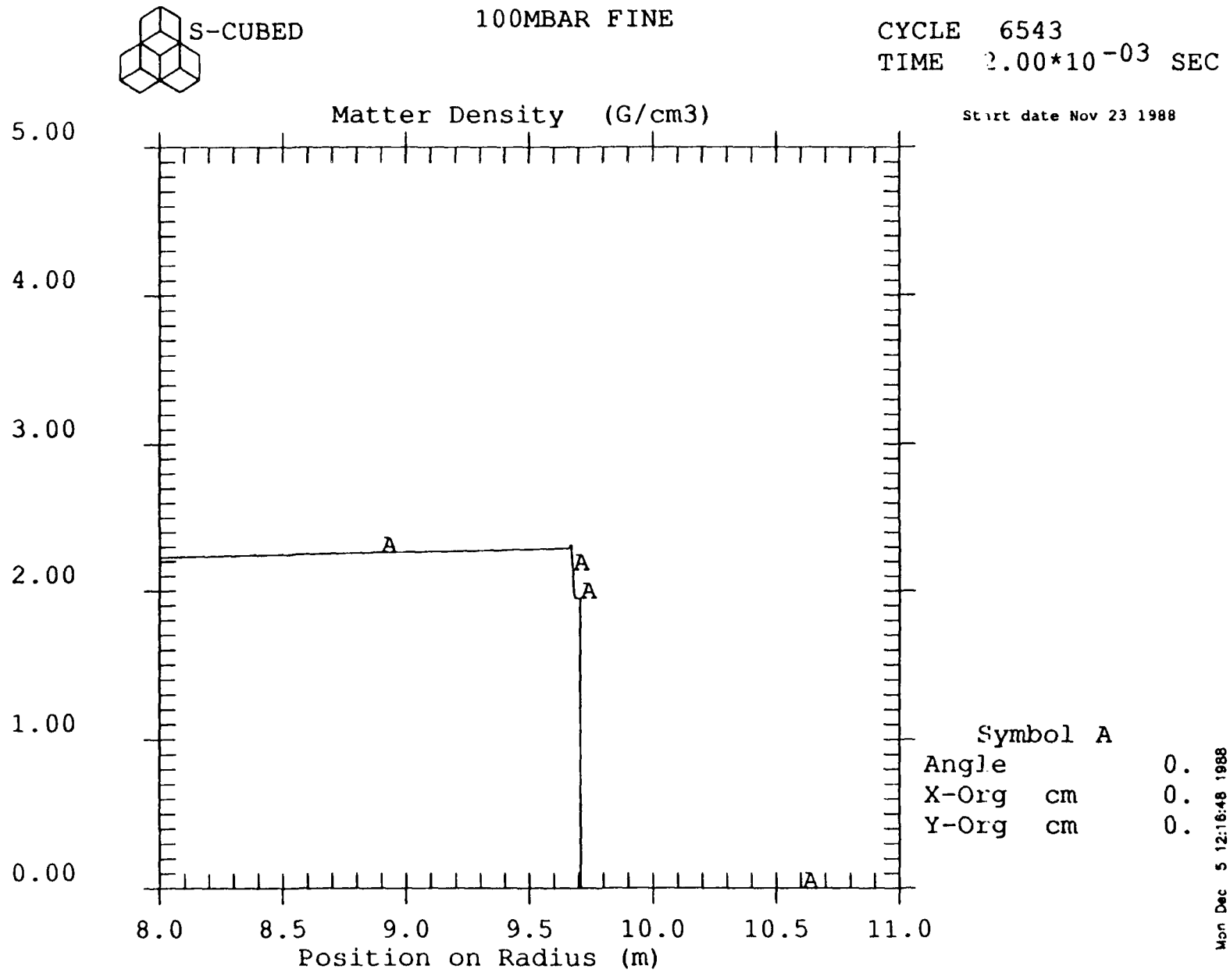
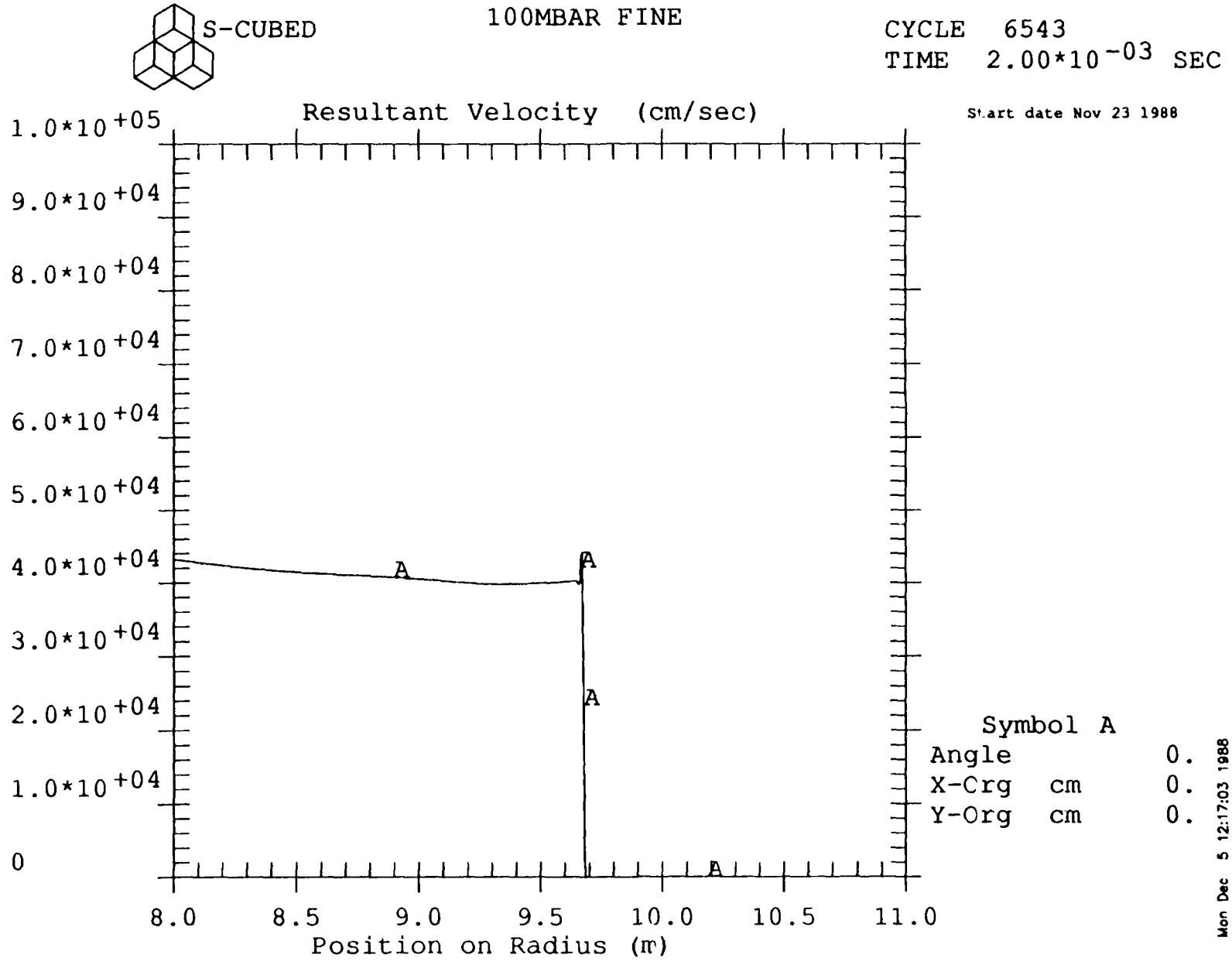
Y-Org cm 0.
Mon Dec 5 12:13:58 1988

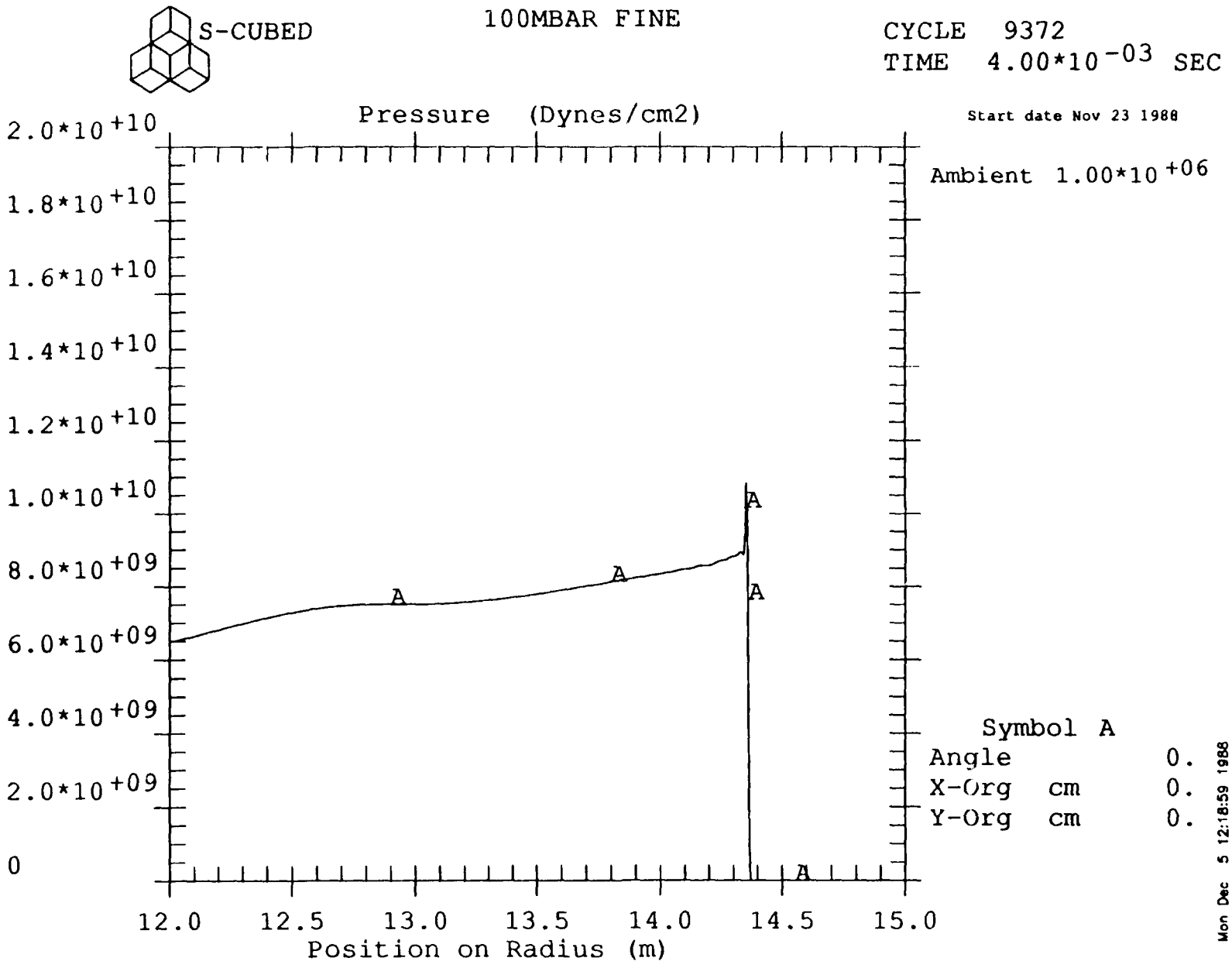

S-CUBED
100MBAR FINE
CYCLE 4682
TIME 1.00*10-03 SEC
Matter Density (G/cm3)
Start date Nov 23 1988
5.00
4.00
3.00
2.00
1.00
0.00
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:14:14 1988

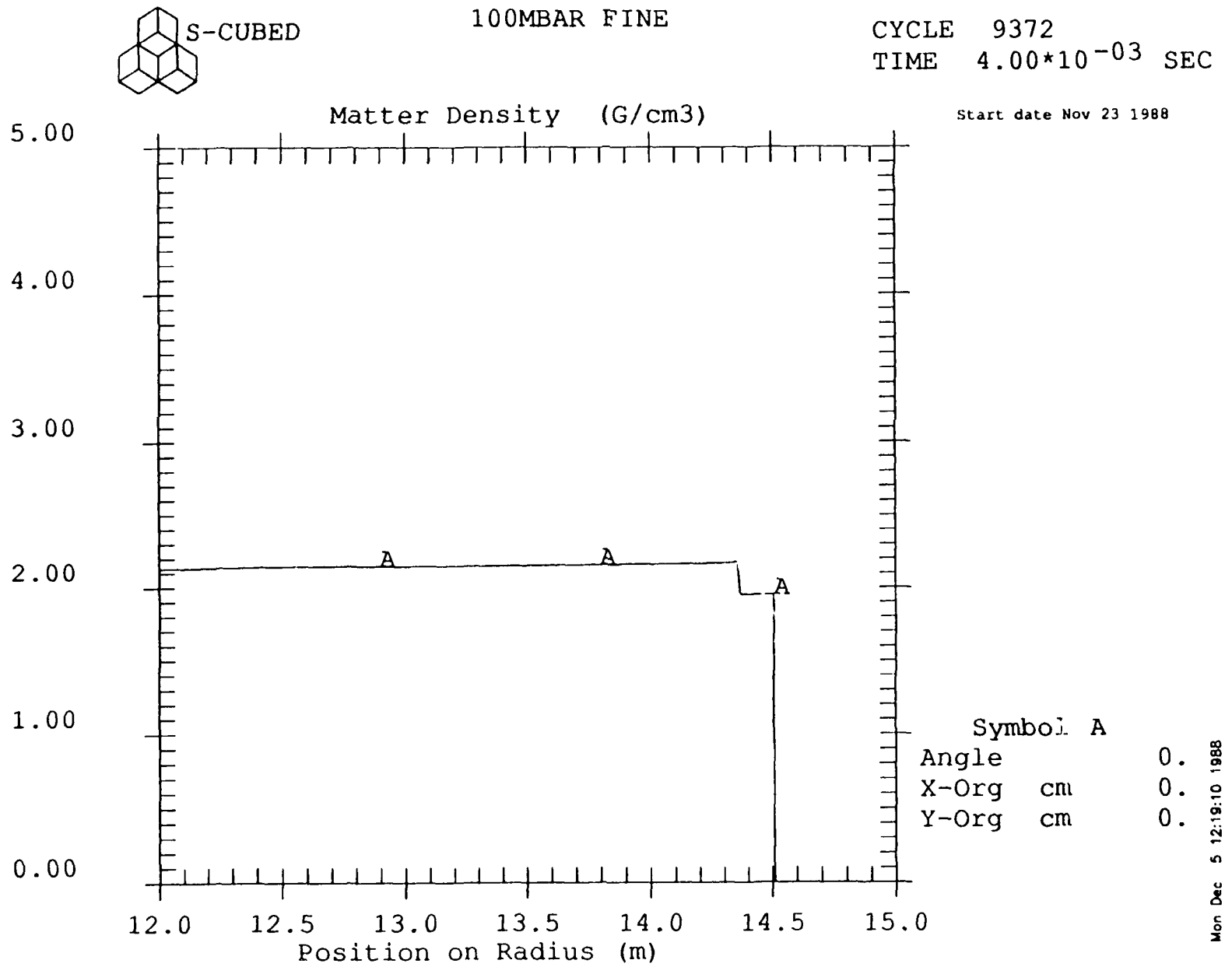

S-CUBED
100MBAR FINE
CYCLE 4682
TIME 1.00*10 -03 SEC
Start date Nov 23 1988
Resultant Velocity (cm/sec)
2.0*10 +05
1.8*10 +05
1.6*10 +05
1.4*10 +05
1.2*10 +05
1.0*10 +05
8.0*10 +04
6.0*10 +04
4.0*10 +04
2.0*10 +04
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:14:36 1988

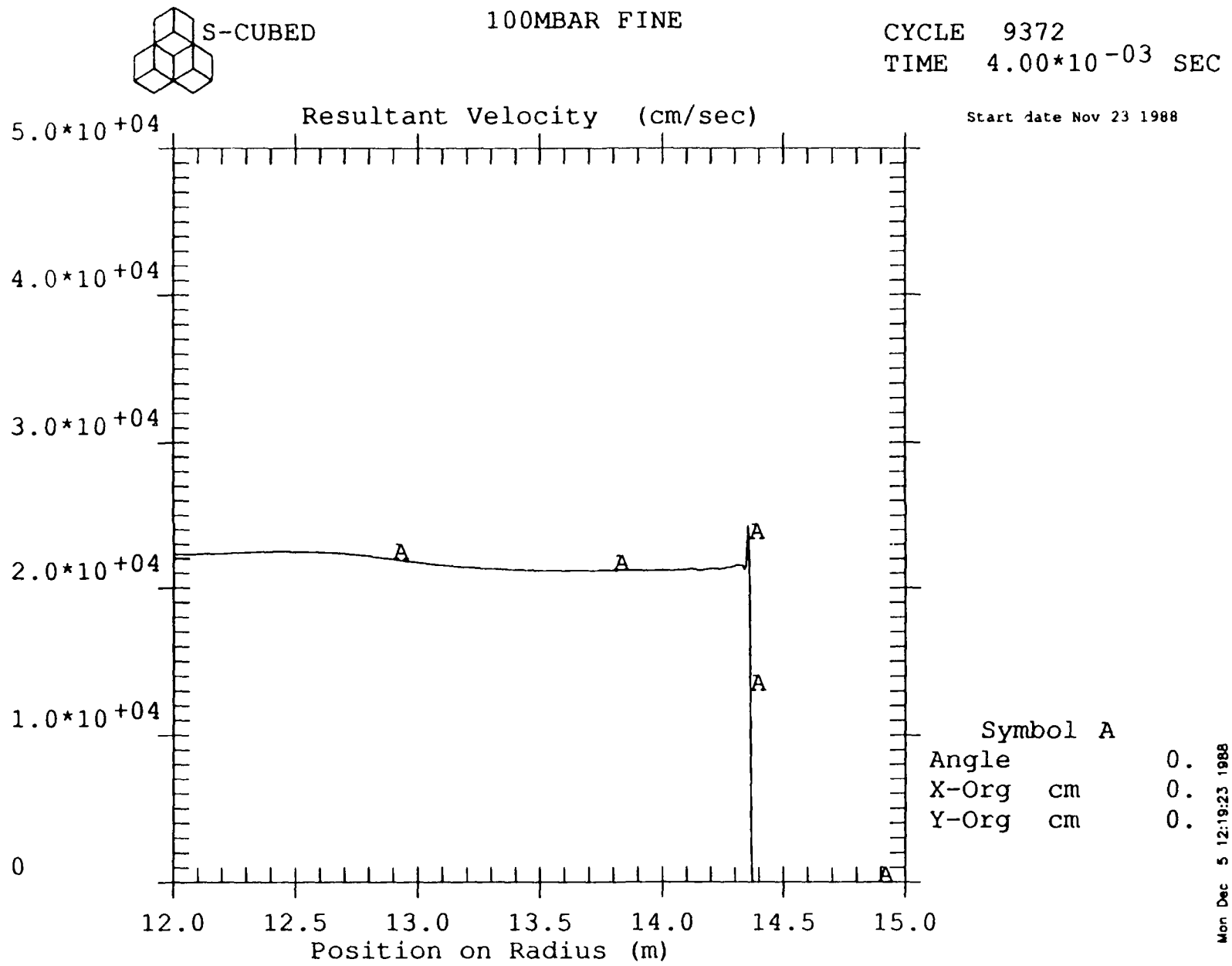

S-CUBED
100MBAR FINE
CYCLE 6543
TIME 2.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Nov 23 1988
Ambient 1.00*10 +06
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:16:35 1988


S-CUBED
100MBAR FINE
CYCLE 6543
TIME 2.00*10 -03 SEC
Matter Density (G/cm3)
Start date Nov 23 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
A
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:16:48 1988

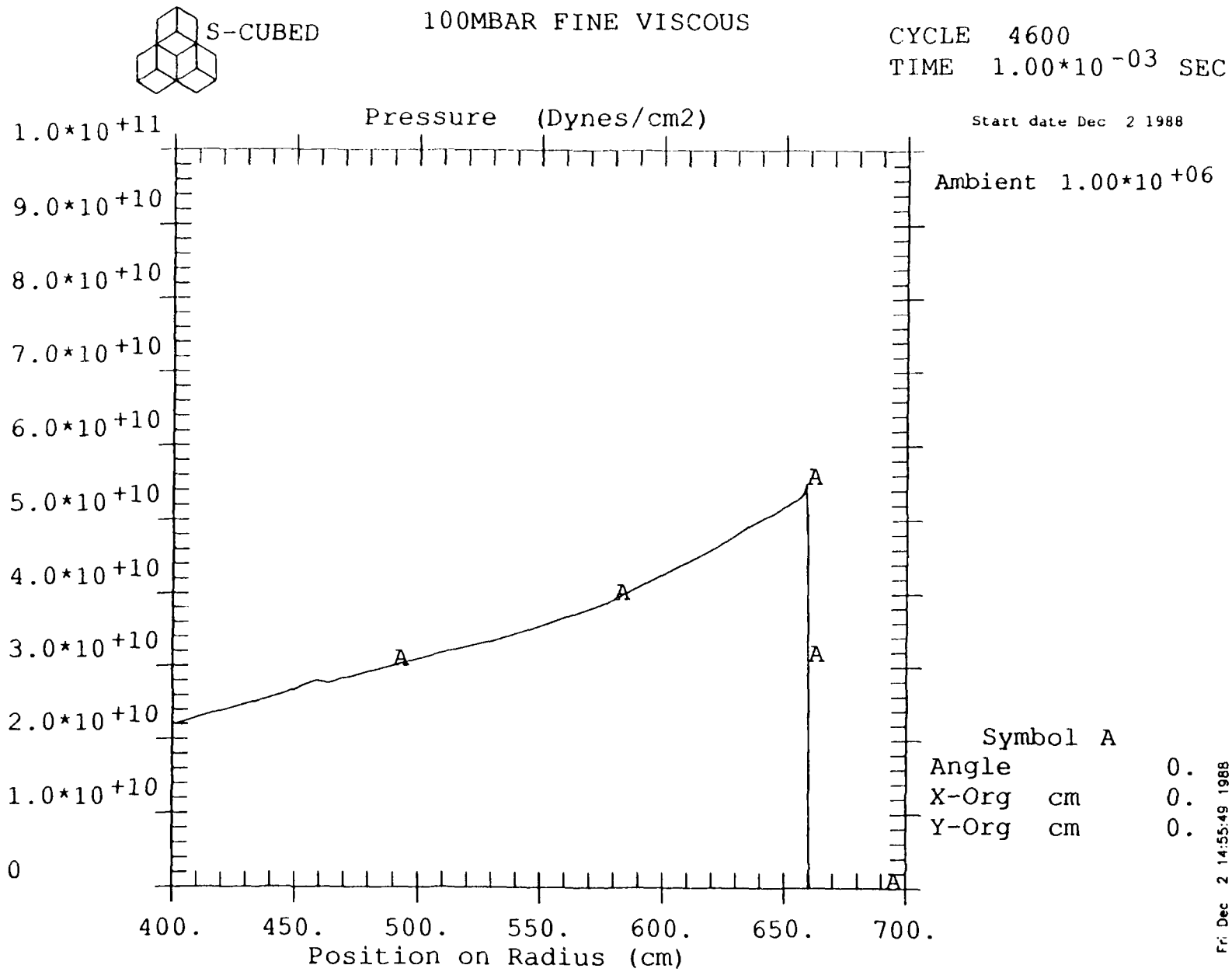

S-CUBED
100MBAR FINE
CYCLE 6543
TIME 2.00*10-03 SEC
Start date Nov 23 1988
Resultant Velocity (cm/sec)
1.0*10+05
9.0*10+04
8.0*10+04
7.0*10+04
6.0*10+04
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Crg cm 0.
Y-Org cm 0.
Mon Dec 5 12:17:03 1988

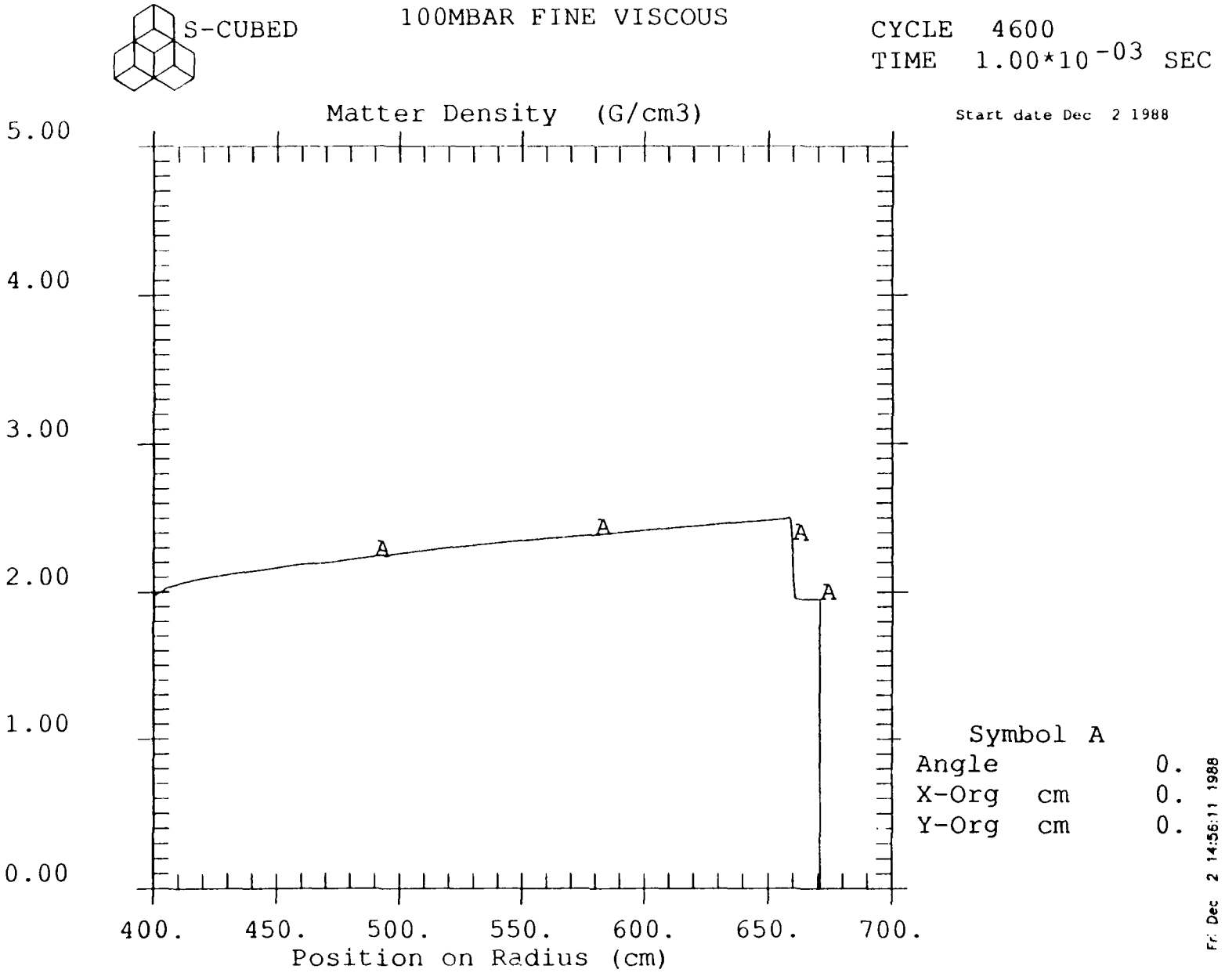

S-CUBED
100MBAR FINE
CYCLE 9372
TIME 4.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Nov 23 1988
Ambient 1.00*10 +06
2.0*10 +10
1.8*10 +10
1.6*10 +10
1.4*10 +10
1.2*10 +10
1.0*10 +10
8.0*10 +09
6.0*10 +09
4.0*10 +09
2.0*10 +09
0
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:18:59 1988

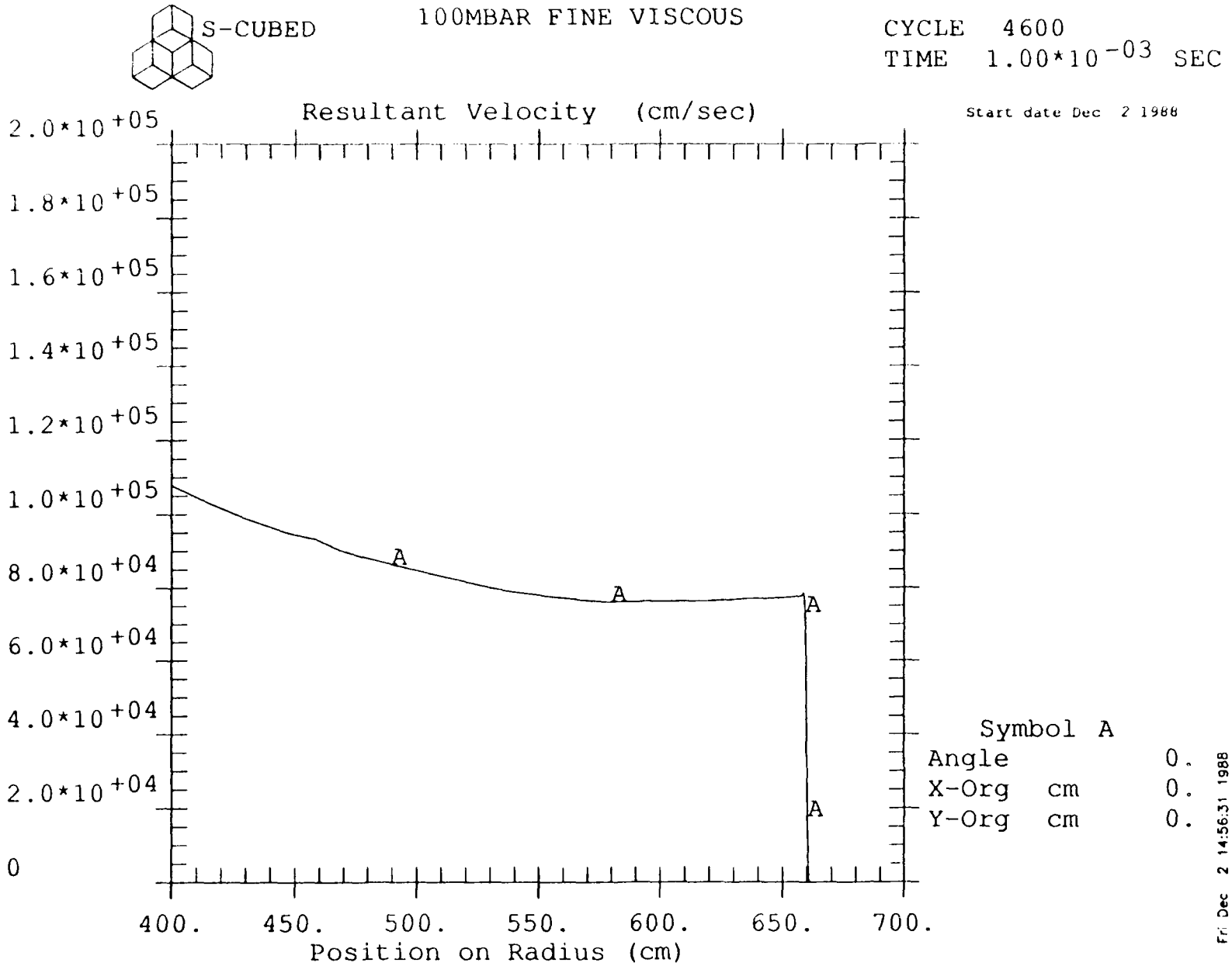

S-CUBED
100MBAR FINE
CYCLE 9372
TIME 4.00*10-03 SEC
Matter Density (G/cm3)
Start date Nov 23 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:19:10 1988

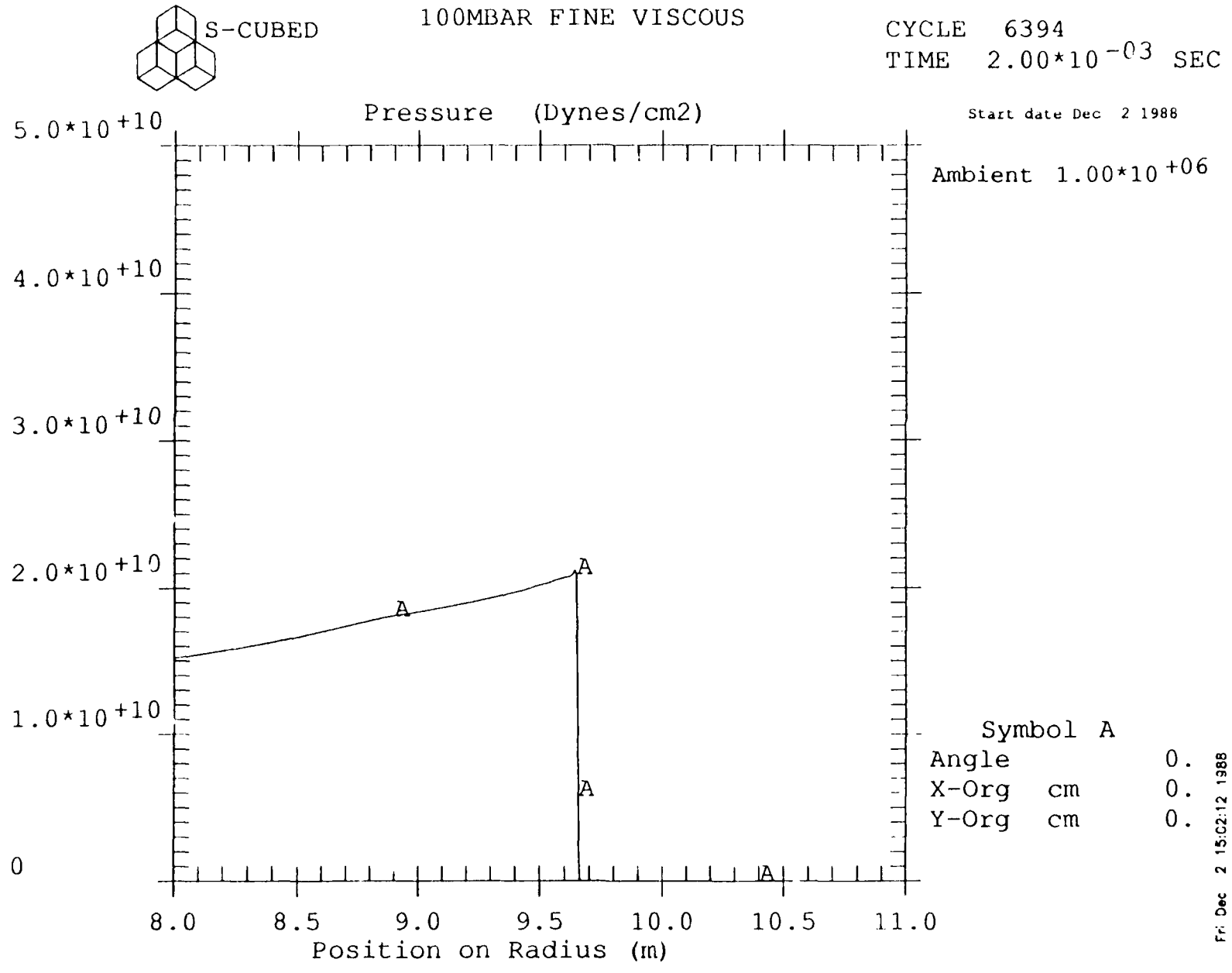

S-CUBED
100MBAR FINE
CYCLE 9372
TIME 4.00*10 -03 SEC
Resultant Velocity (cm/sec)
Start date Nov 23 1988
5.0*10 +04
4.0*10 +04
3.0*10 +04
2.0*10 +04
1.0*10 +04
0
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Mon Dec 5 12:19:23 1988

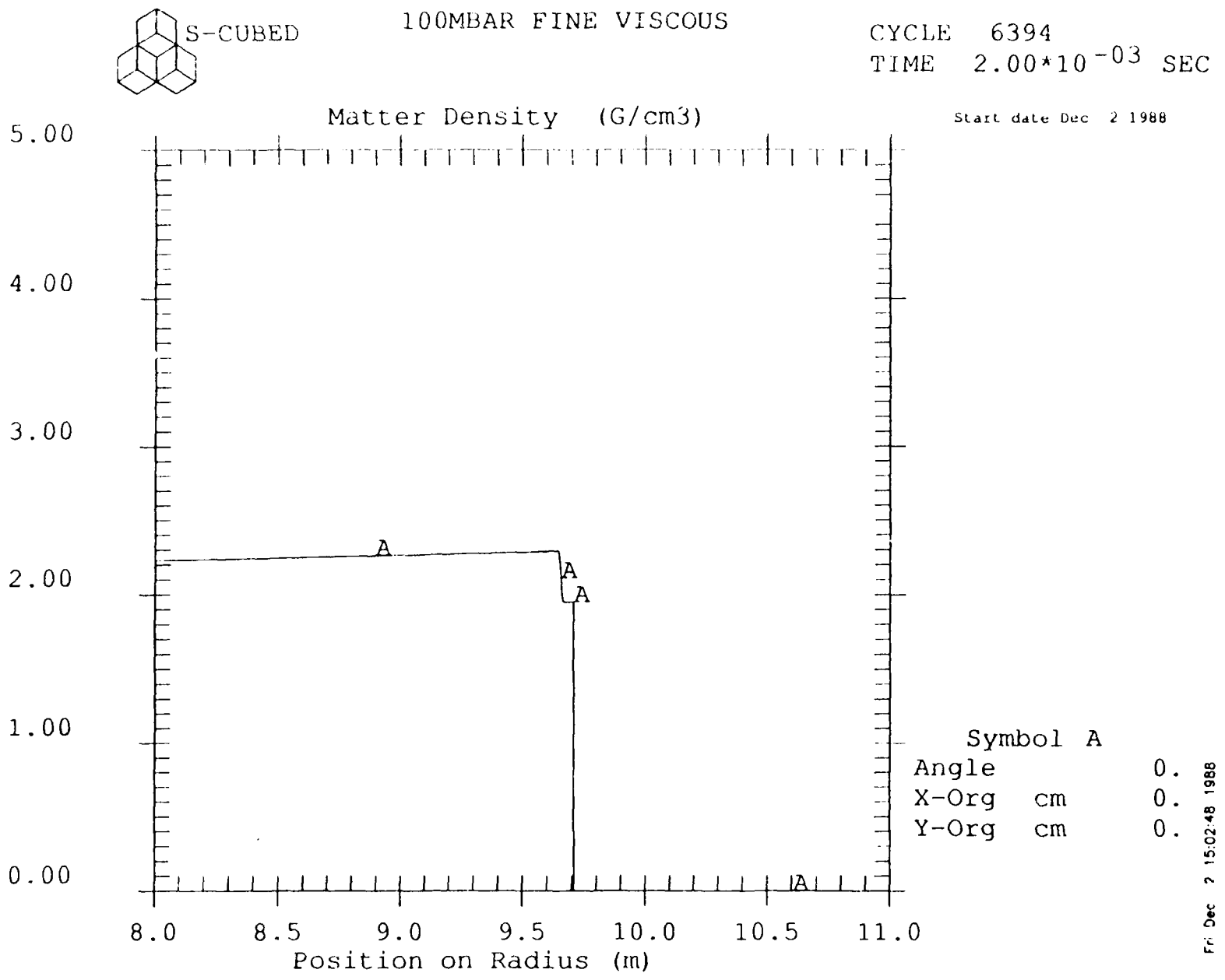
APPENDIX C
STREAK WITH $C_L = 0.5$
FINE ZONING

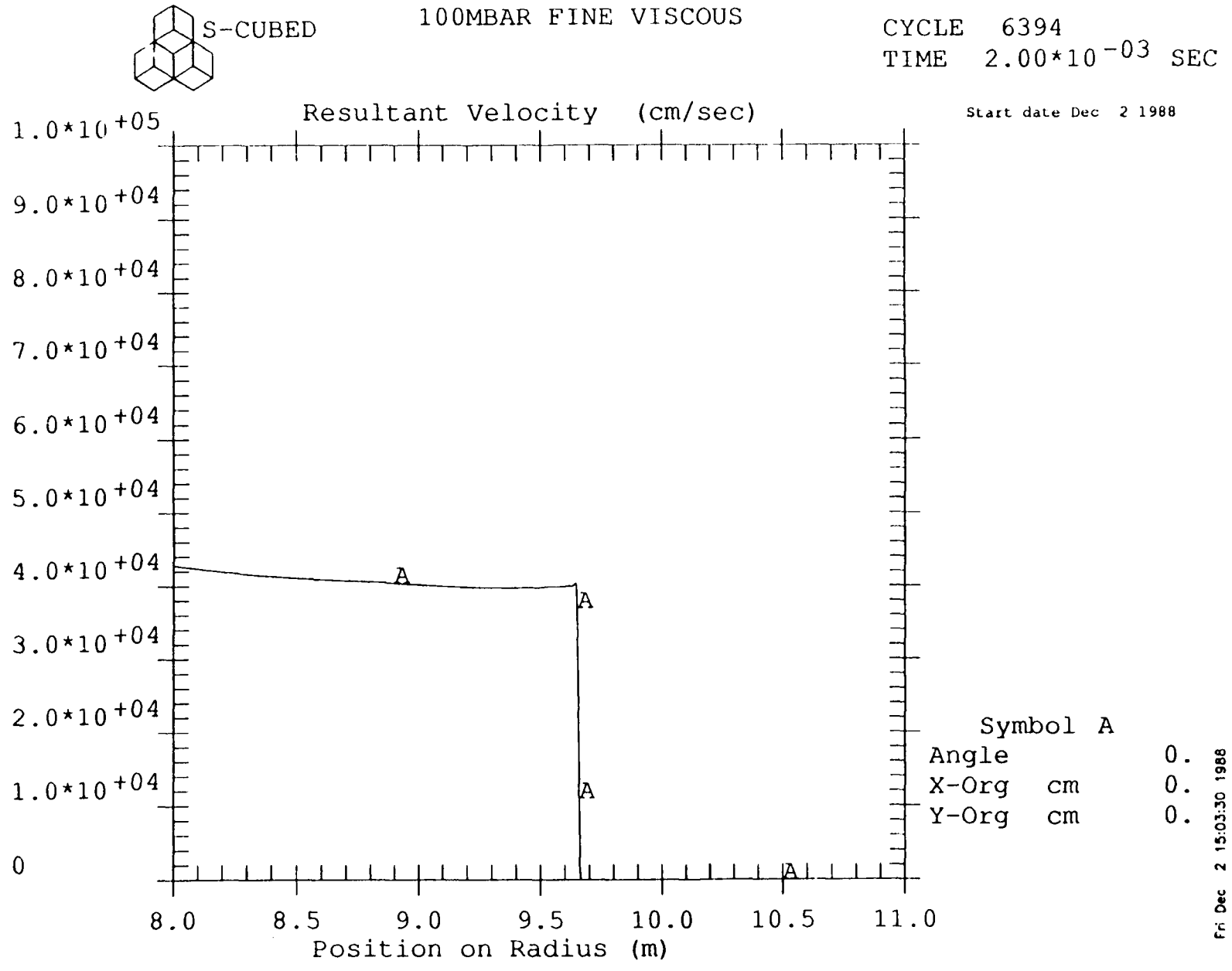

S-CUBED
100MBAR FINE VISCOUS
CYCLE 4600
TIME 1.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 2 1988
Ambient 1.00*10 +06
1.0*10 +11
9.0*10 +10
8.0*10 +10
7.0*10 +10
6.0*10 +10
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 14:55:49 1988

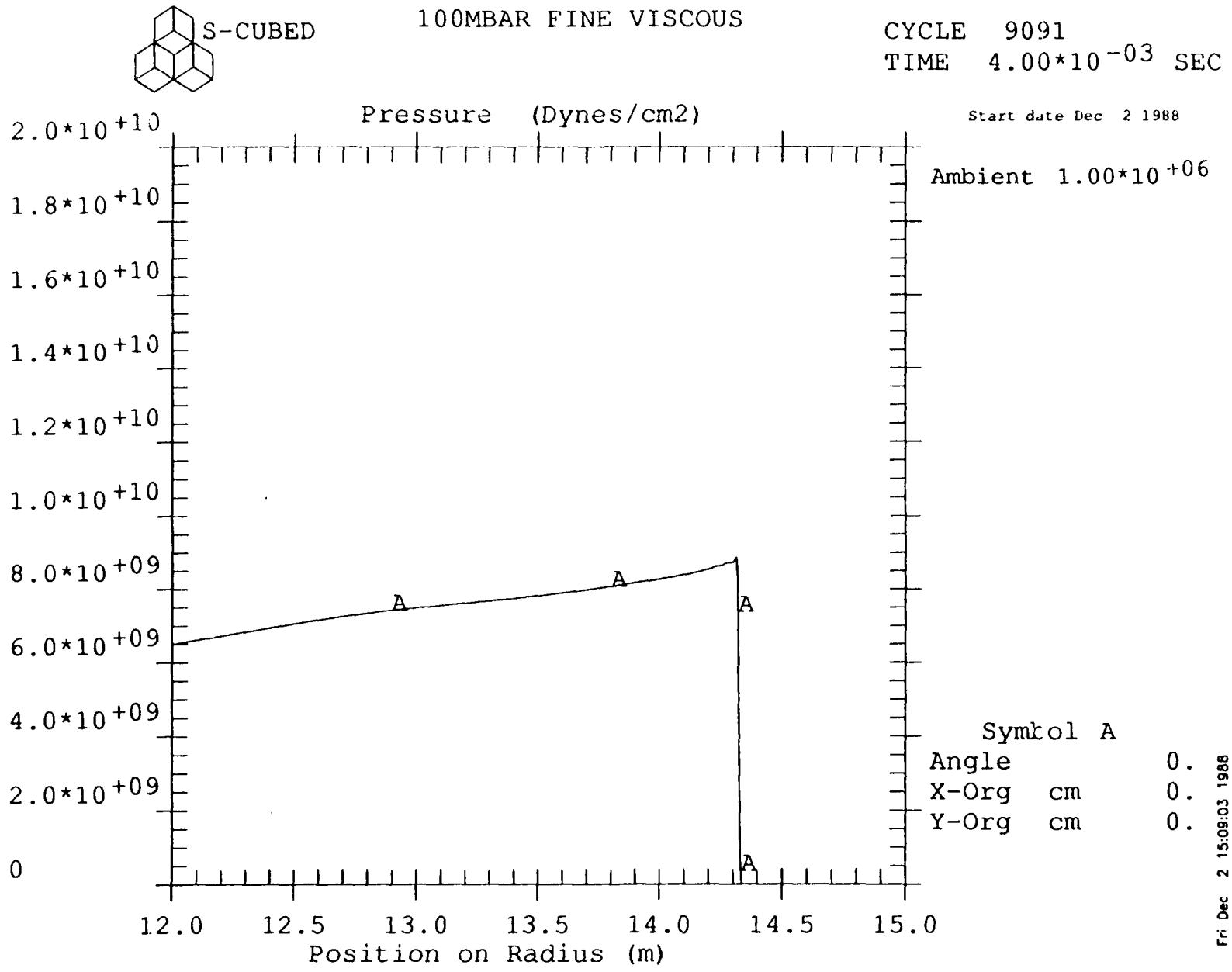

S-CUBED
100MBAR FINE VISCOUS
CYCLE 4600
TIME 1.00*10 -03 SEC
Matter Density (G/cm3)
Start date Dec 2 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
A
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 14:56:11 1988

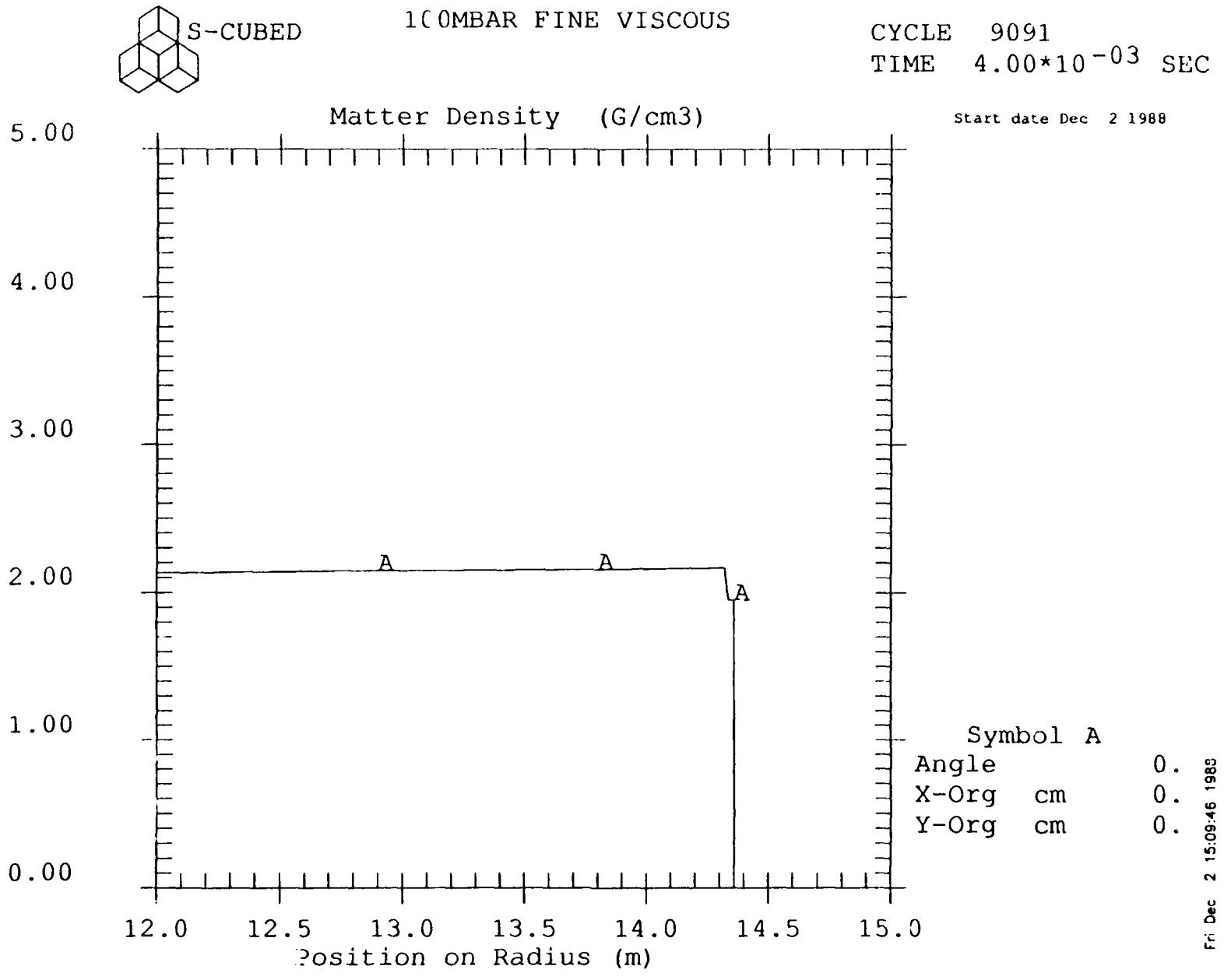

S-CUBED
100MBAR FINE VISCOUS
CYCLE 4600
TIME 1.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 2 1988
2.0*10+05
1.8*10+05
1.6*10+05
1.4*10+05
1.2*10+05
1.0*10+05
8.0*10+04
6.0*10+04
4.0*10+04
2.0*10+04
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 14:56:31 1988

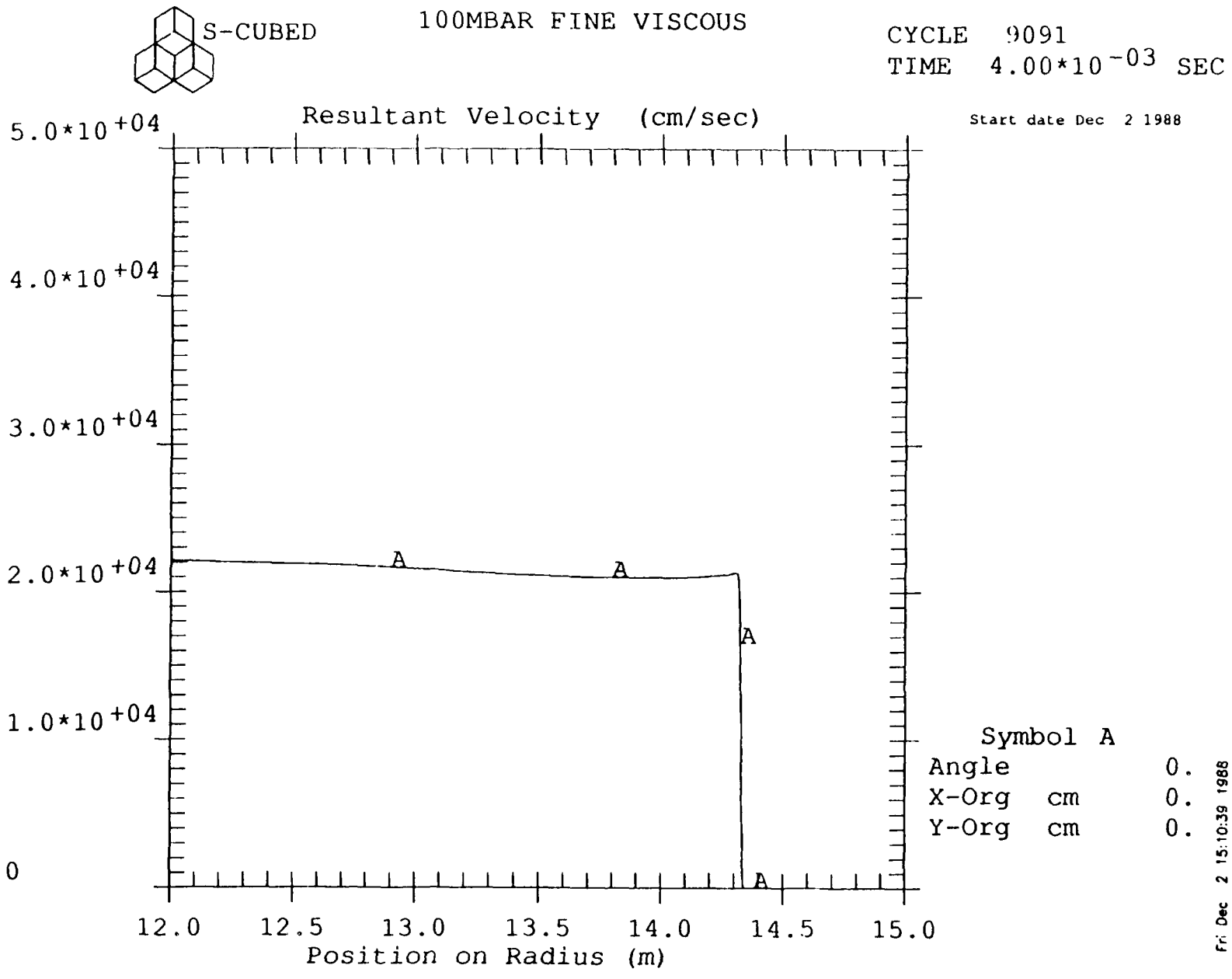

S-CUBED
100MBAR FINE VISCOUS
CYCLE 6394
TIME 2.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 2 1988
Ambient 1.00*10 +06
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
A
A
A
A
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 15:02:12 1988


S-CUBED
100MBAR FINE VISCOUS
CYCLE 6394
TIME 2.00*10-03 SEC
Matter Density (G/cm3)
Start date Dec 2 1988
5.00
4.00
3.00
2.00
1.00
0.00
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 15:02:48 1988

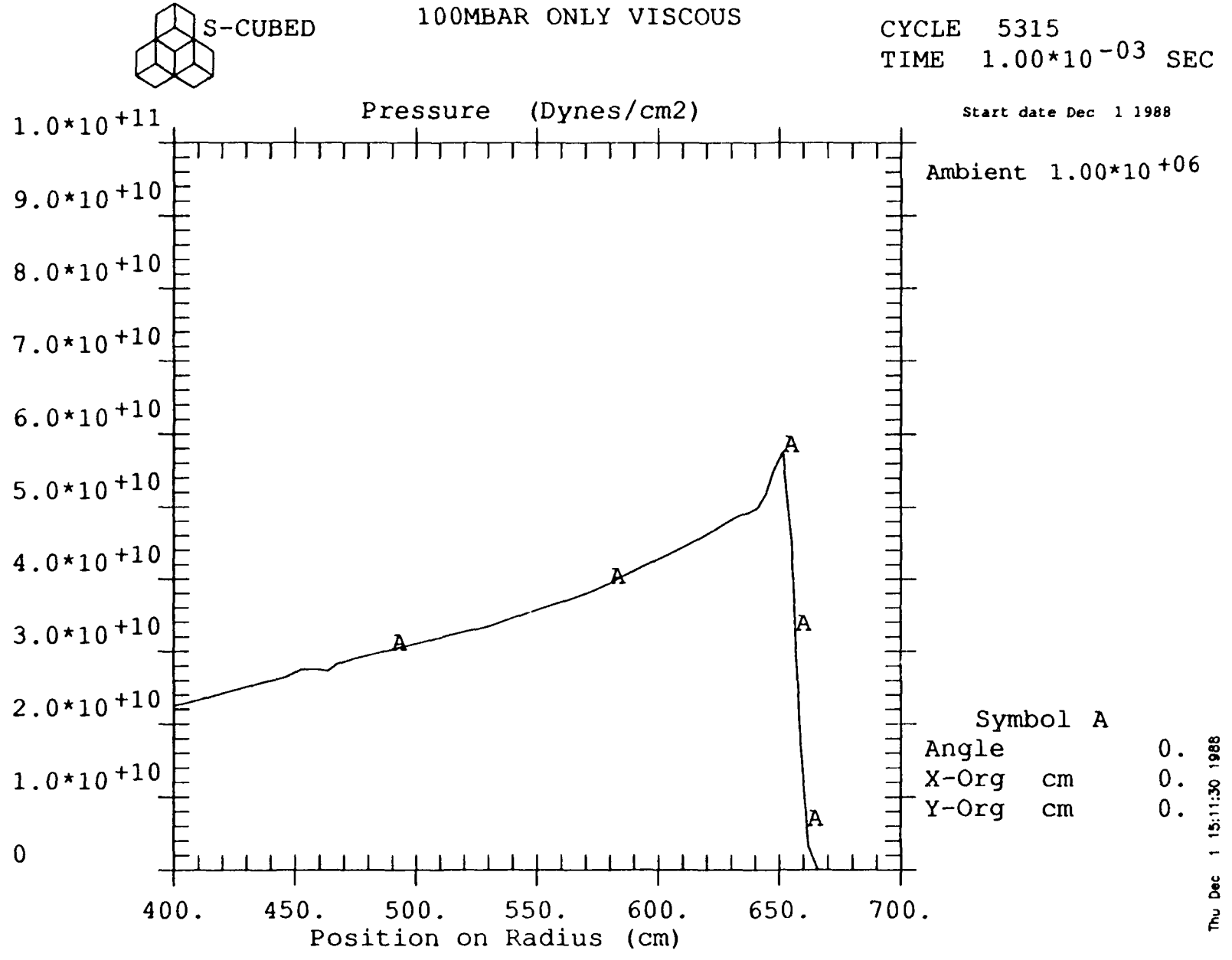

S-CUBED
100MBAR FINE VISCOUS
CYCLE 6394
TIME 2.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 2 1988
1.0*10+05
9.0*10+04
8.0*10+04
7.0*10+04
6.0*10+04
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 15:03:30 1988

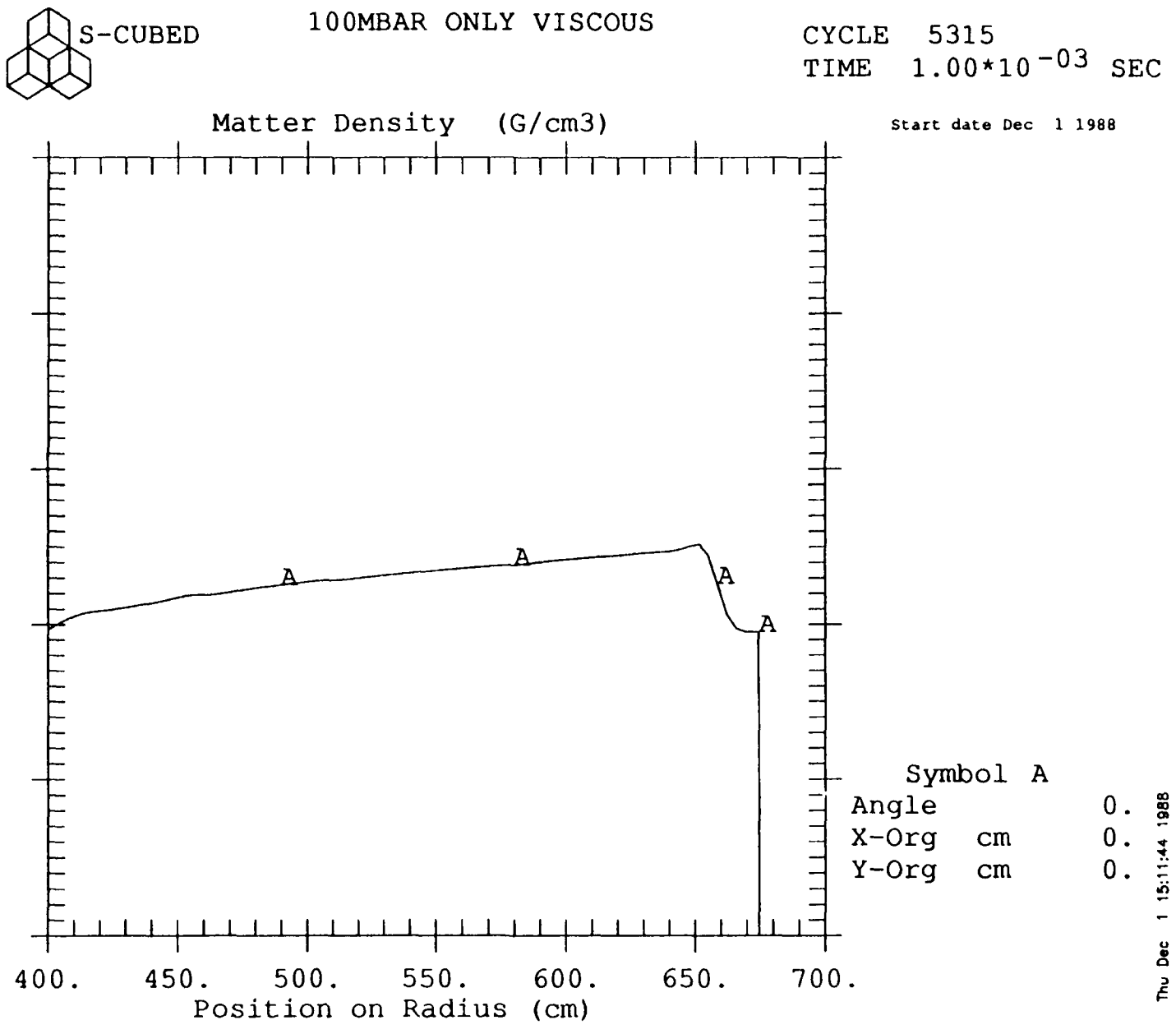

S-CUBED
100MBAR FINE VISCOUS
CYCLE 9091
TIME 4.00*10^-03 SEC
Pressure (Dynes/cm2)
Start date Dec 2 1988
Ambient 1.00*10^+06
2.0*10^+10
1.8*10^+10
1.6*10^+10
1.4*10^+10
1.2*10^+10
1.0*10^+10
8.0*10^+09
6.0*10^+09
4.0*10^+09
2.0*10^+09
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Fri Dec 2 15:09:03 1988

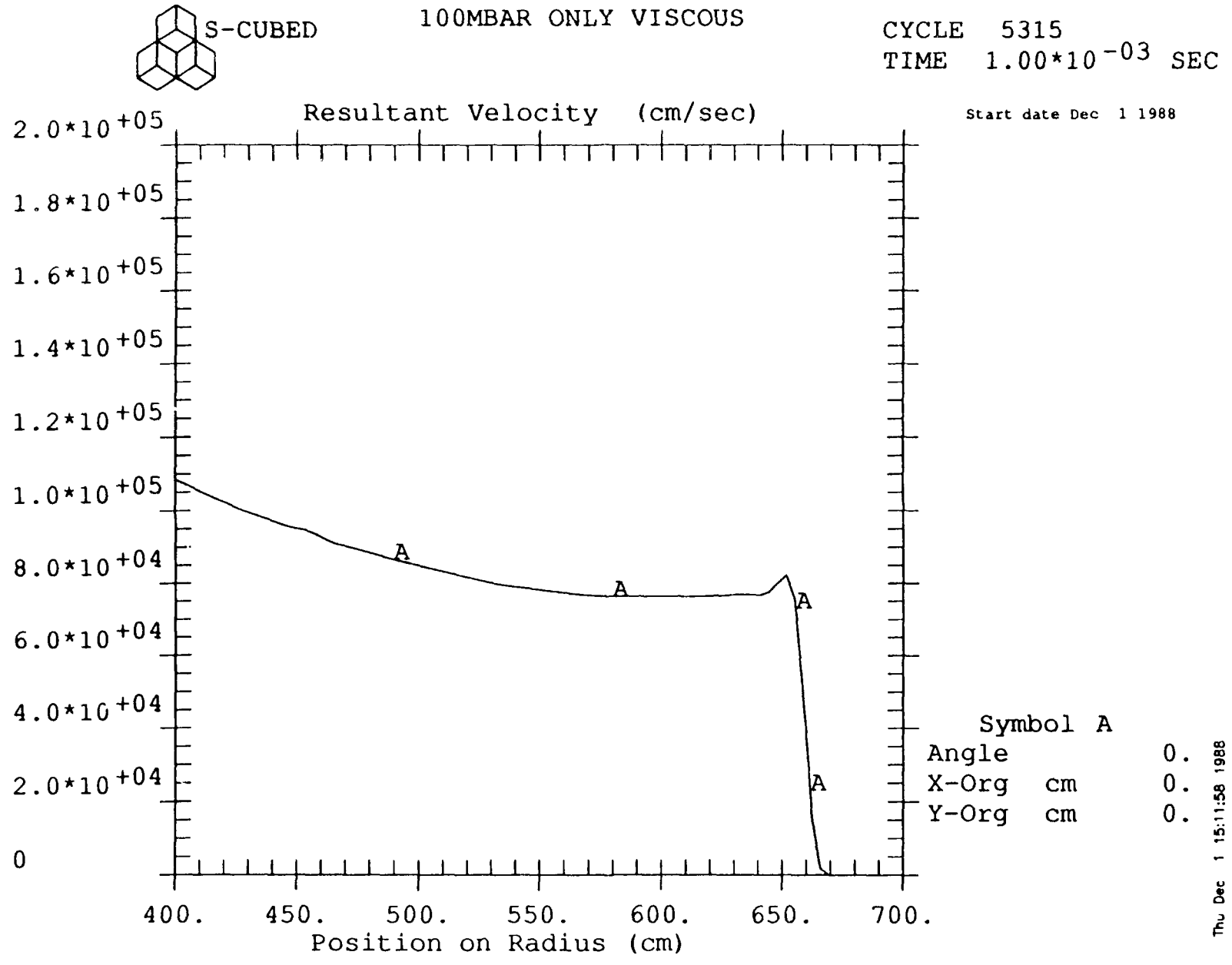

S-CUBED
100MBAR FINE VISCOUS
CYCLE 9091
TIME 4.00*10-03 SEC
Matter Density (G/cm3)
Start date Dec 2 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 15:09:46 1988

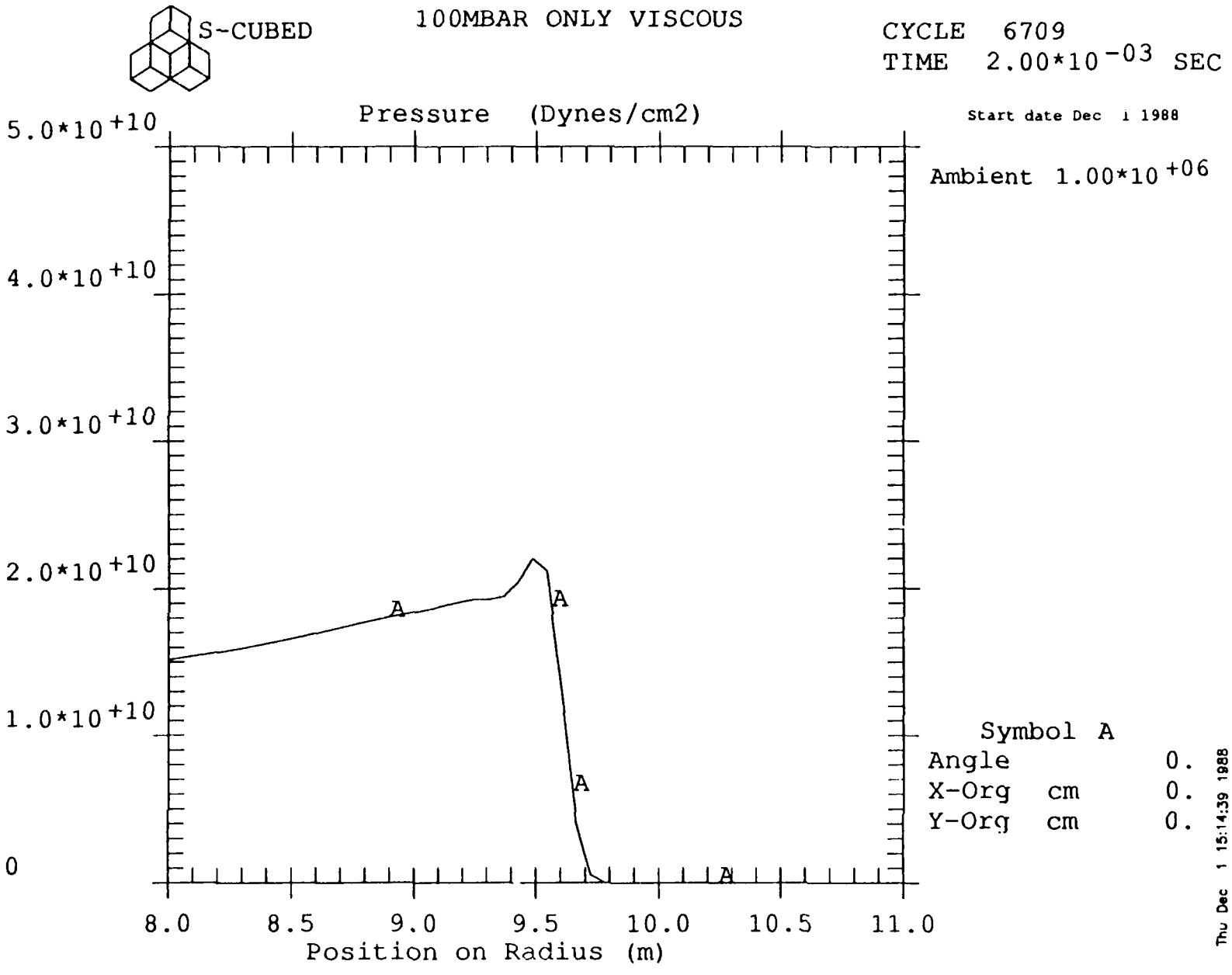

S-CUBED
100MBAR FINE VISCOUS
CYCLE 9091
TIME 4.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 2 1988
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
A
A
A
A
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 2 15:10:39 1988

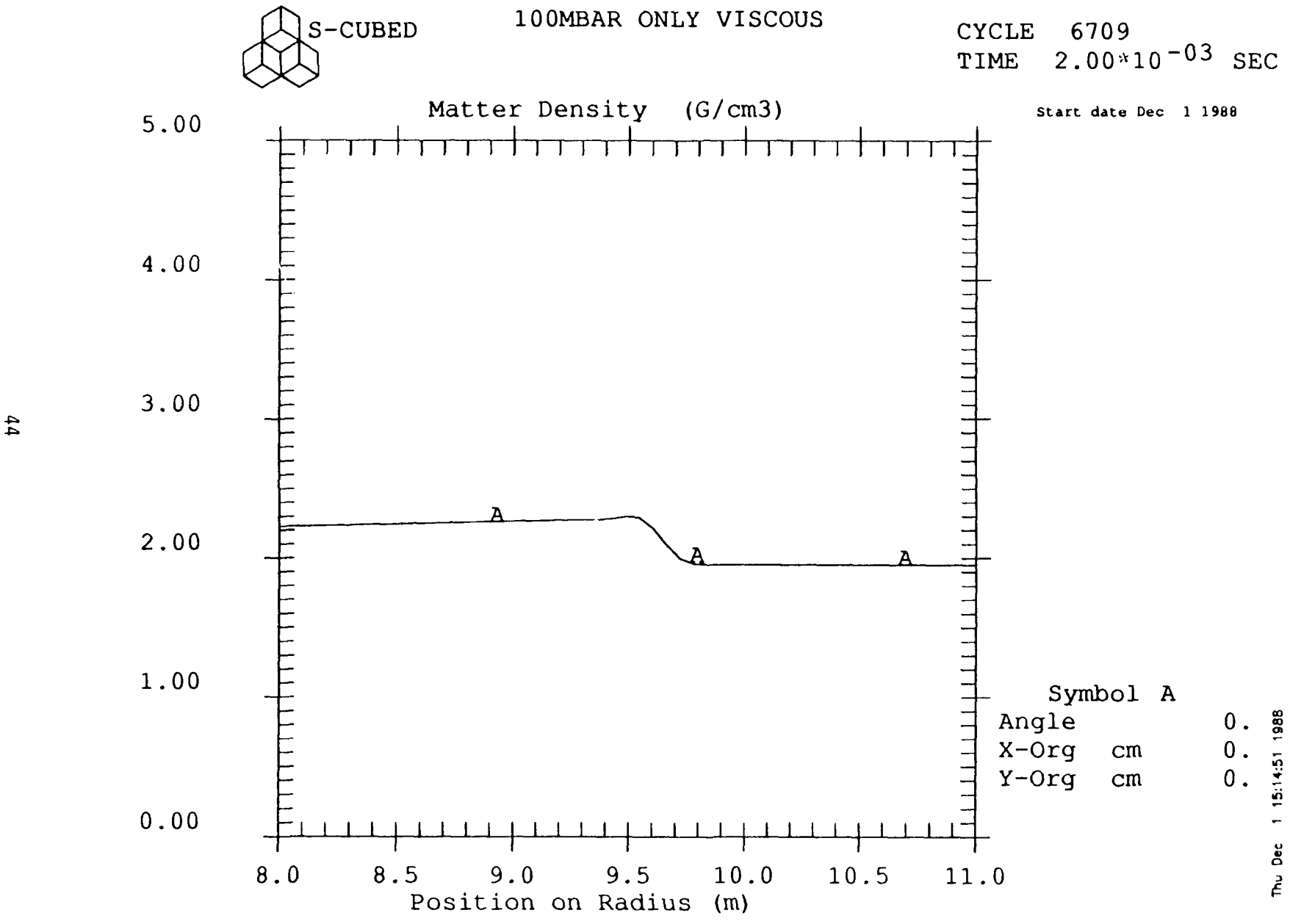
APPENDIX D
STREAK WITH $C_L = 0.5$
COARSE ZONING

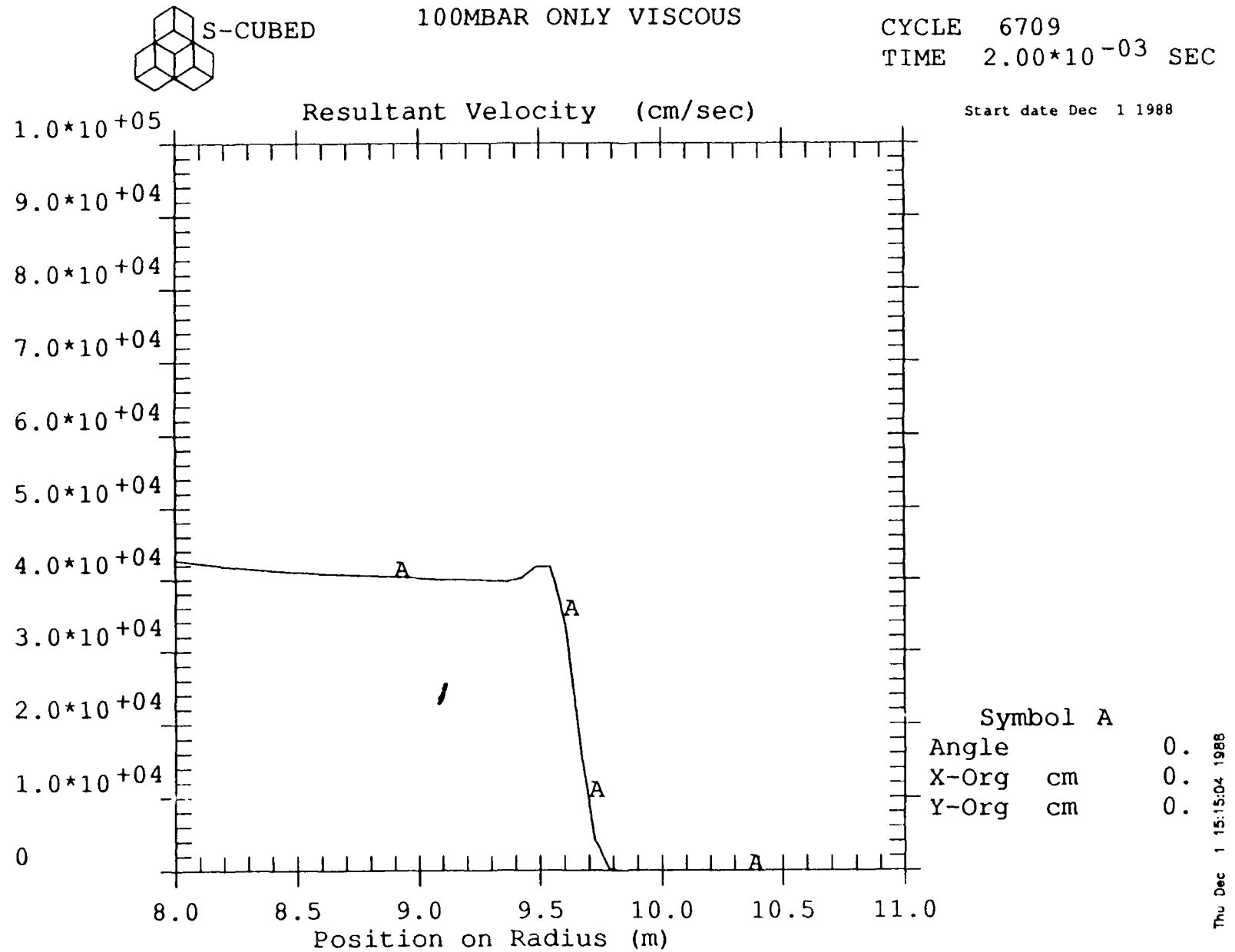

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 5315
TIME 1.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 1 1988
Ambient 1.00*10 +06
1.0*10 +11
9.0*10 +10
8.0*10 +10
7.0*10 +10
6.0*10 +10
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:11:30 1988

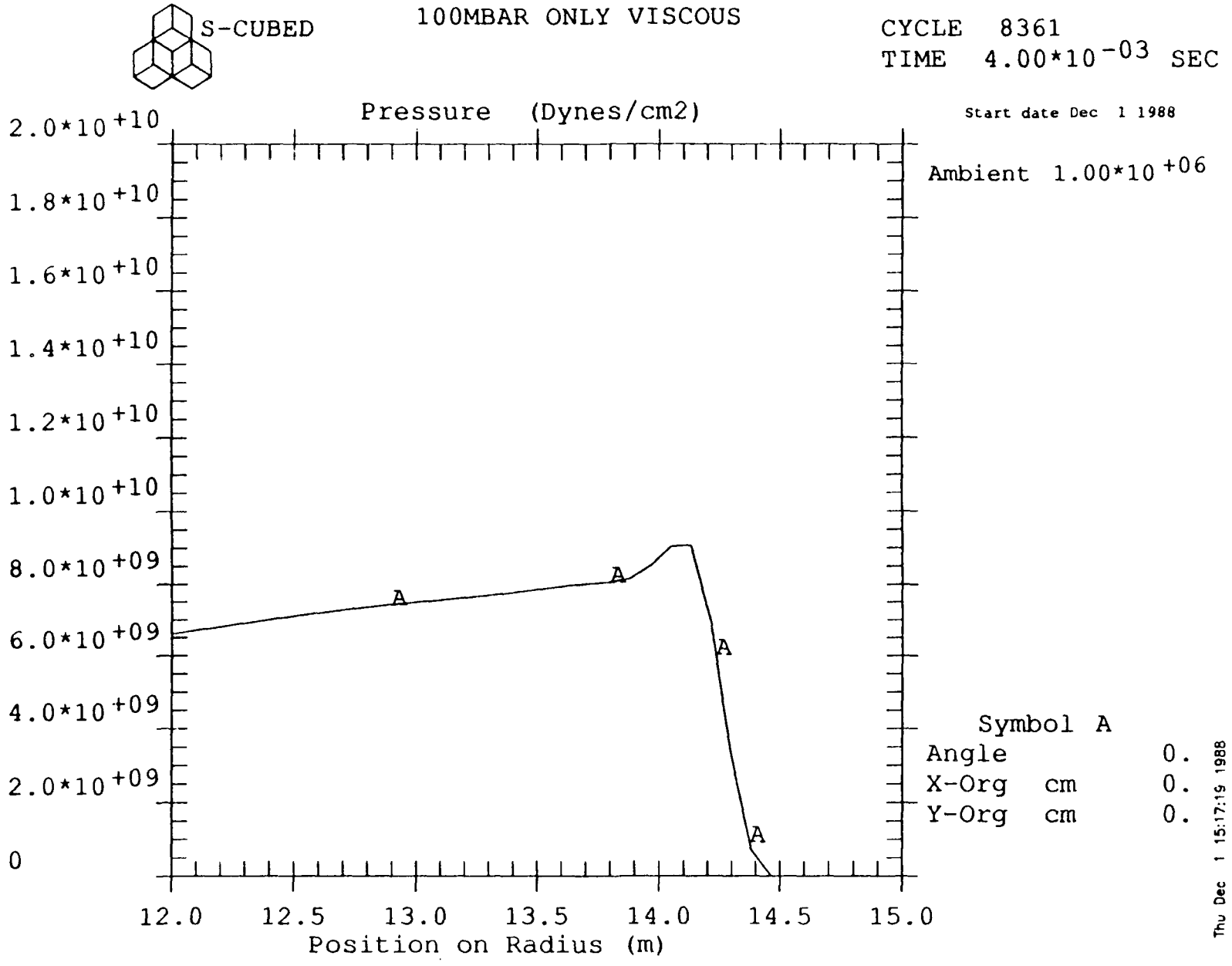

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 5315
TIME 1.00*10 -03 SEC
Matter Density (G/cm3)
Start date Dec 1 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
A
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:11:44 1988

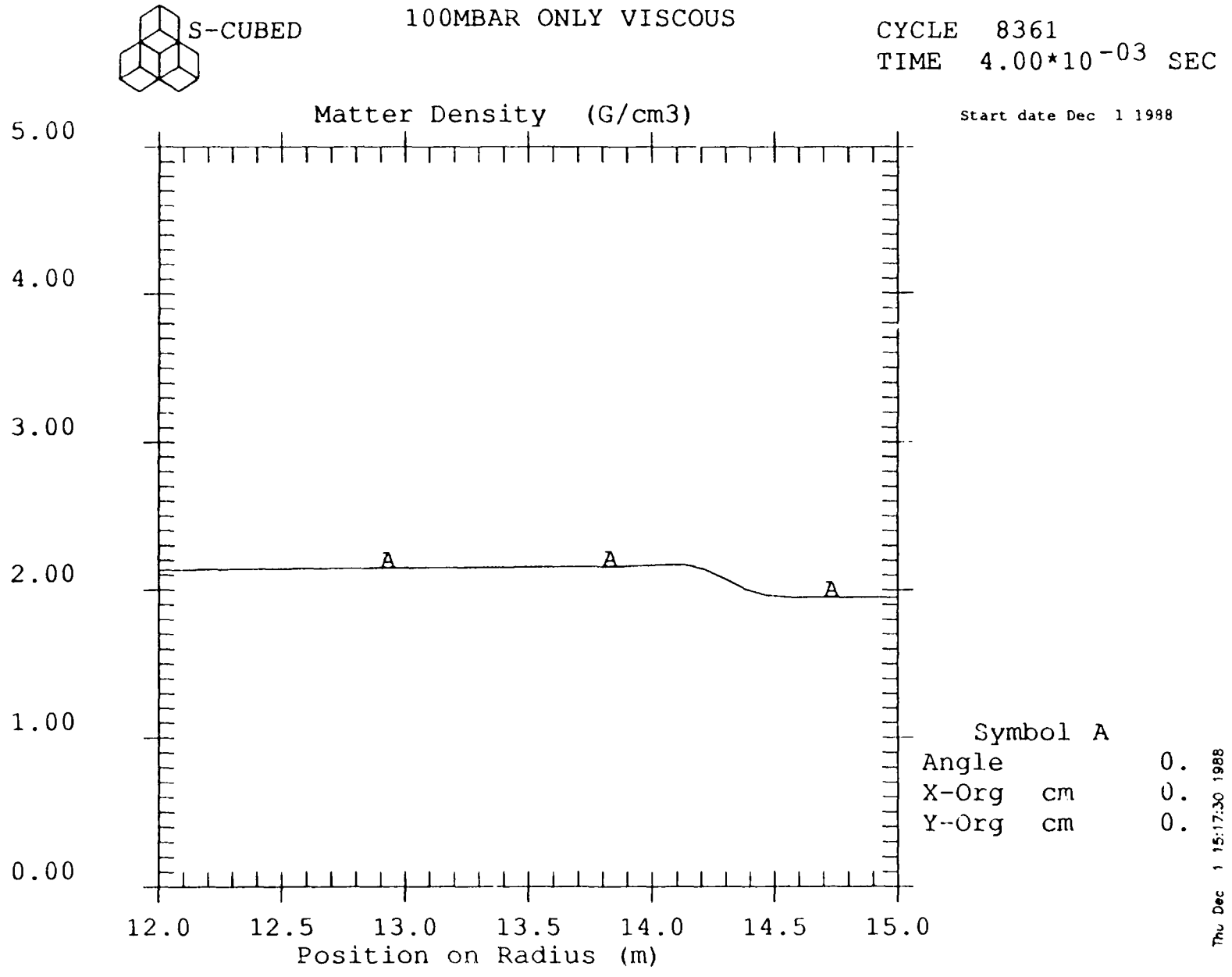

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 5315
TIME 1.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 1 1988
2.0*10+05
1.8*10+05
1.6*10+05
1.4*10+05
1.2*10+05
1.0*10+05
8.0*10+04
6.0*10+04
4.0*10+04
2.0*10+04
0
400.
450.
500.
550.
600.
650.
700.
Position on Radius (cm)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:11:58 1988

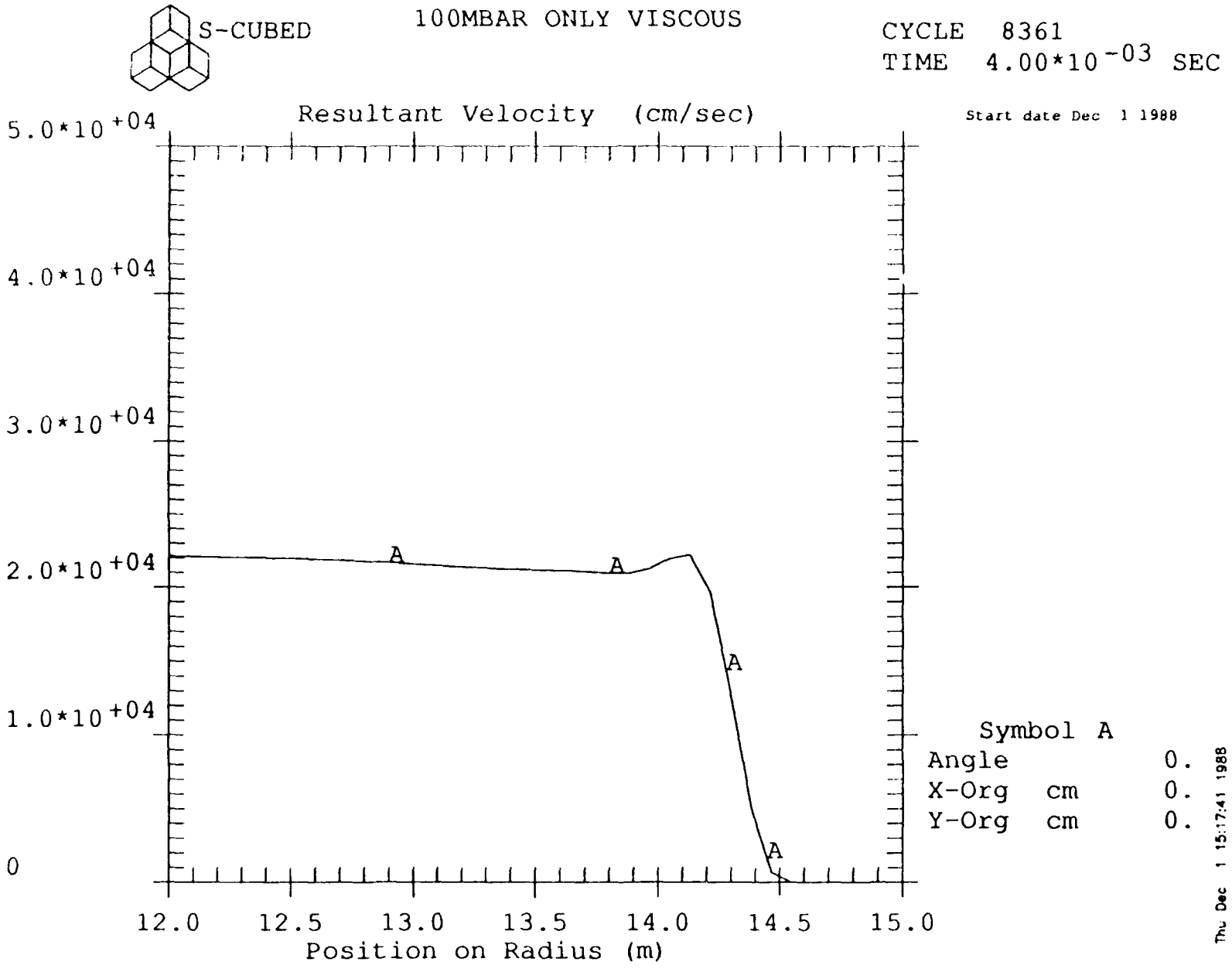

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 6709
TIME 2.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 1 1988
Ambient 1.00*10 +06
5.0*10 +10
4.0*10 +10
3.0*10 +10
2.0*10 +10
1.0*10 +10
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Thu Dec 1 15:14:39 1988


S-CUBED
100MBAR ONLY VISCOUS
CYCLE 6709
TIME 2.00*10-03 SEC
Matter Density (G/cm3)
Start date Dec 1 1988
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:14:51 1988

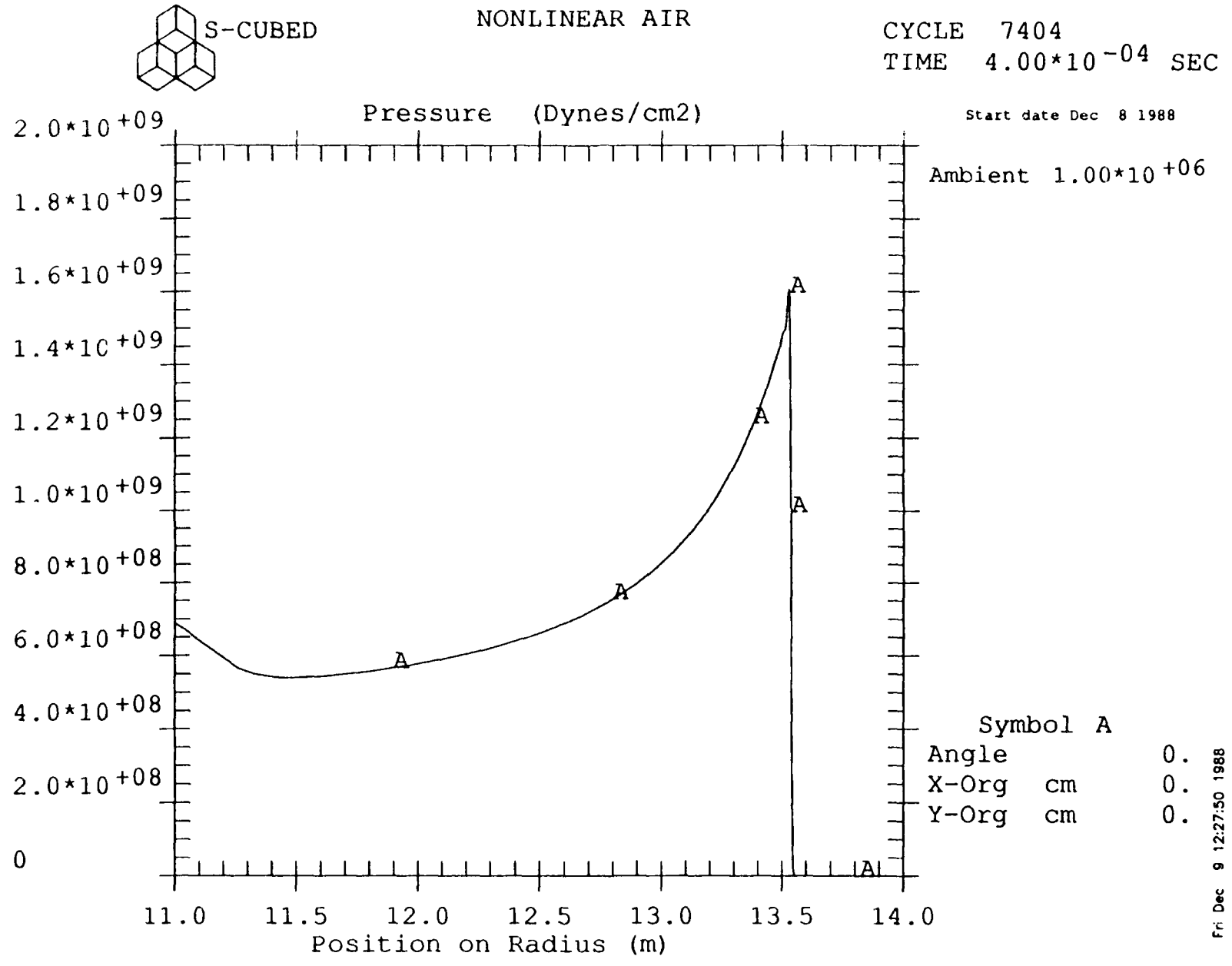

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 6709
TIME 2.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 1 1988
1.0*10+05
9.0*10+04
8.0*10+04
7.0*10+04
6.0*10+04
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:15:04 1988

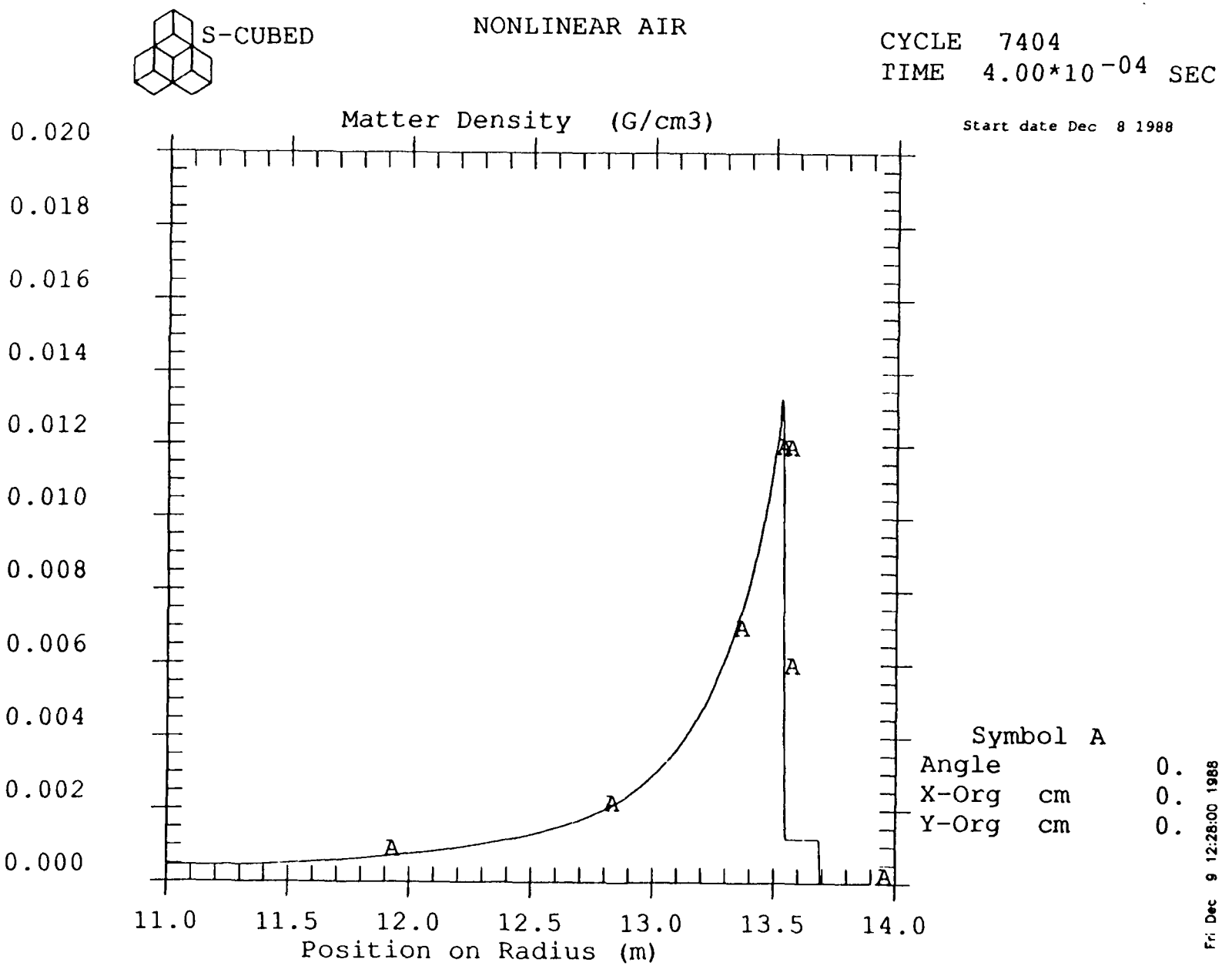

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 8361
TIME 4.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 1 1988
Ambient 1.00*10 +06
2.0*10 +10
1.8*10 +10
1.6*10 +10
1.4*10 +10
1.2*10 +10
1.0*10 +10
8.0*10 +09
6.0*10 +09
4.0*10 +09
2.0*10 +09
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:17:19 1988
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)

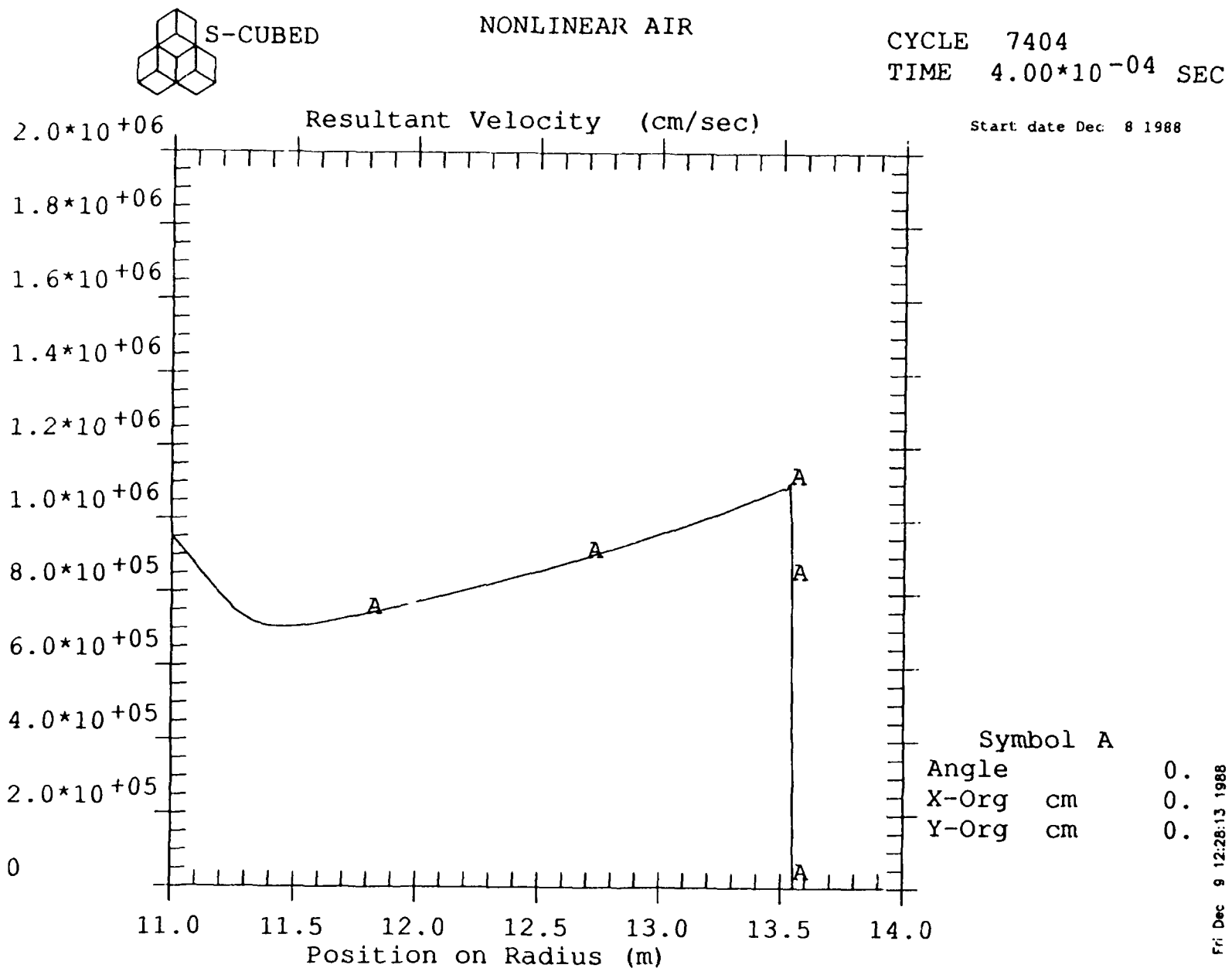

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 8361
TIME 4.00*10^-03 SEC
Start date Dec 1 1988
Matter Density (G/cm3)
5.00
4.00
3.00
2.00
1.00
0.00
A
A
A
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y--Org cm 0.
Thu Dec 1 15:17:30 1988

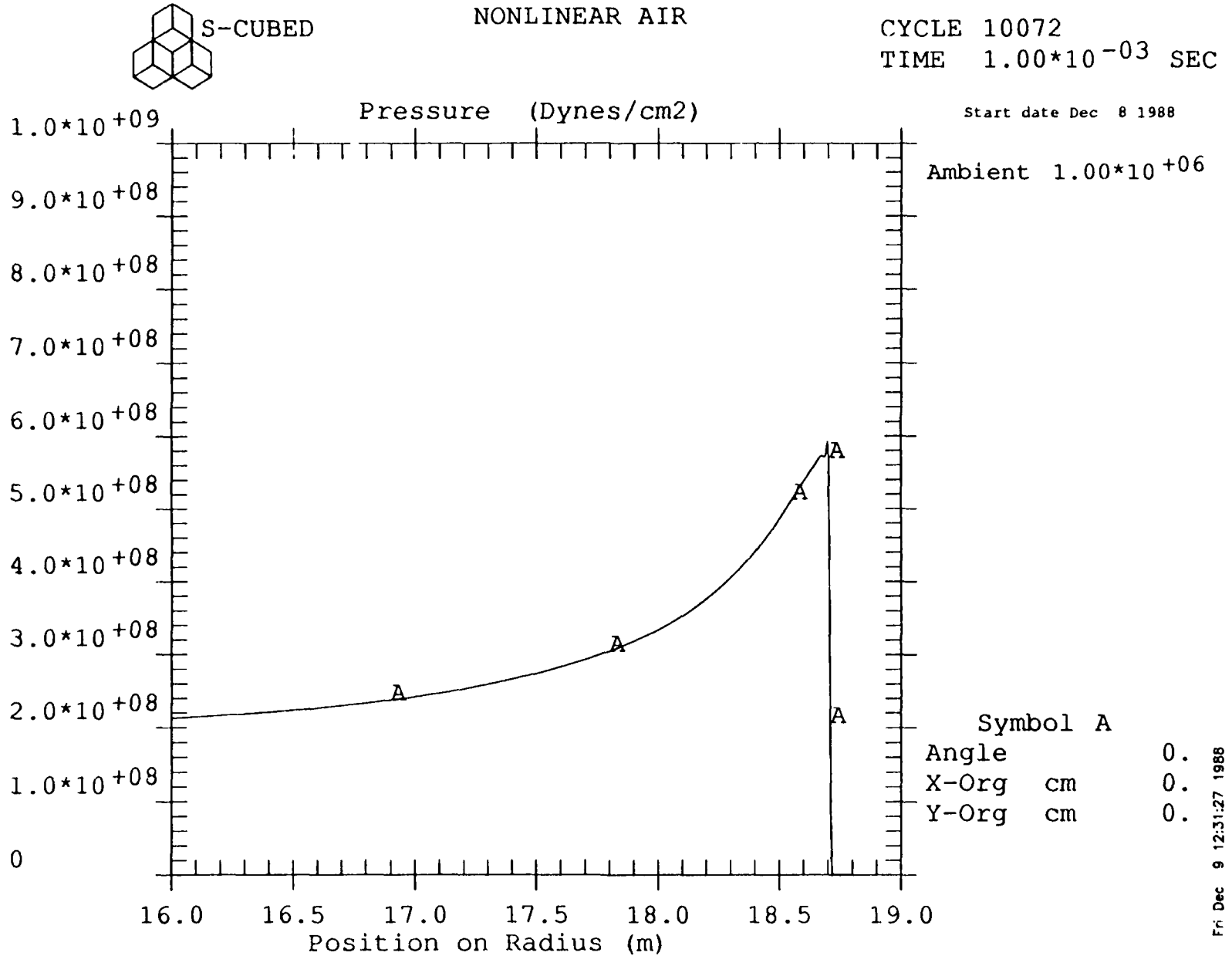

S-CUBED
100MBAR ONLY VISCOUS
CYCLE 8361
TIME 4.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 1 1988
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
12.0
12.5
13.0
13.5
14.0
14.5
15.0
Position on Radius (m)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Dec 1 15:17:41 1988

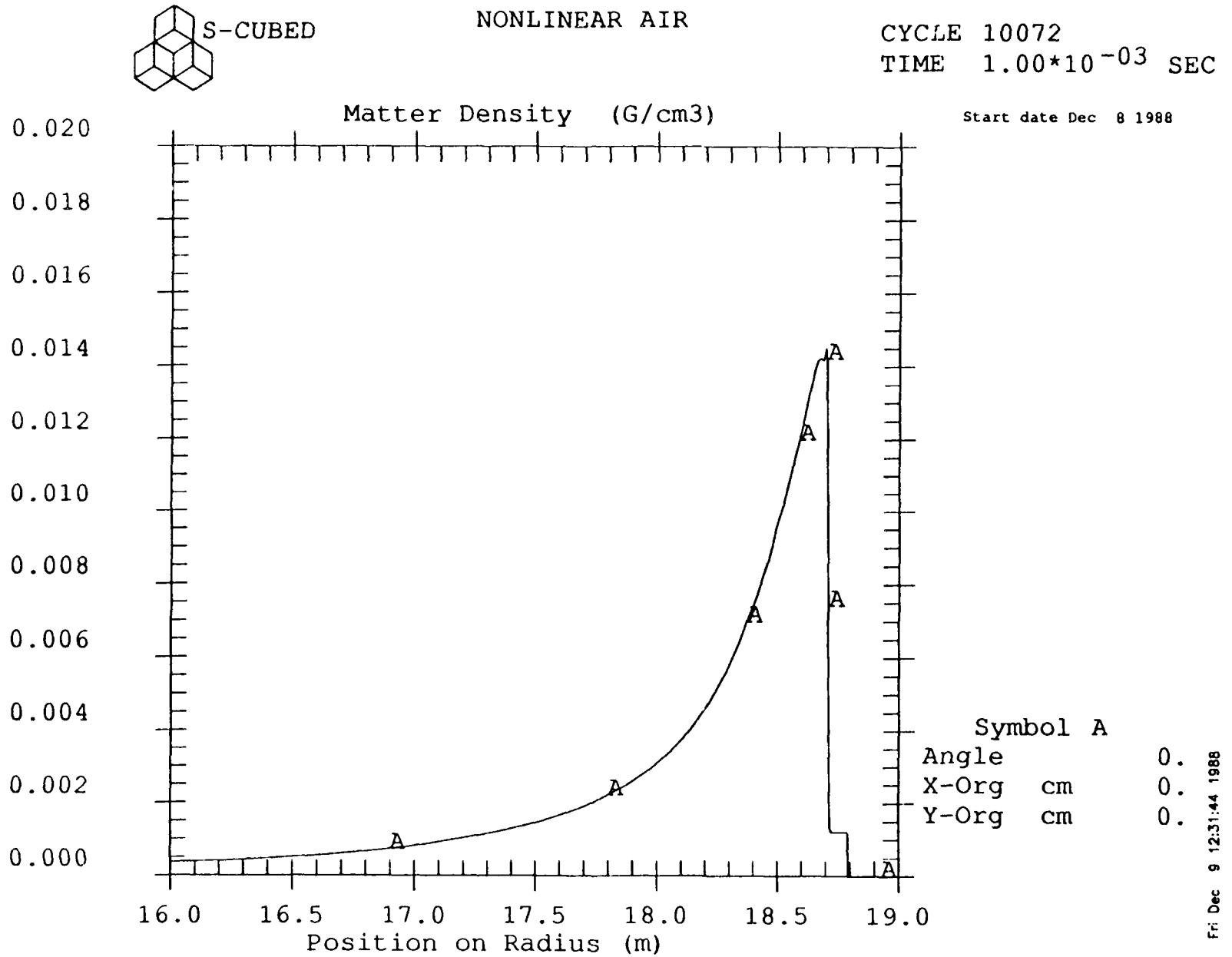
APPENDIX E
STANDARD STREAK
HIGH PRESSURE, FINE ZONING

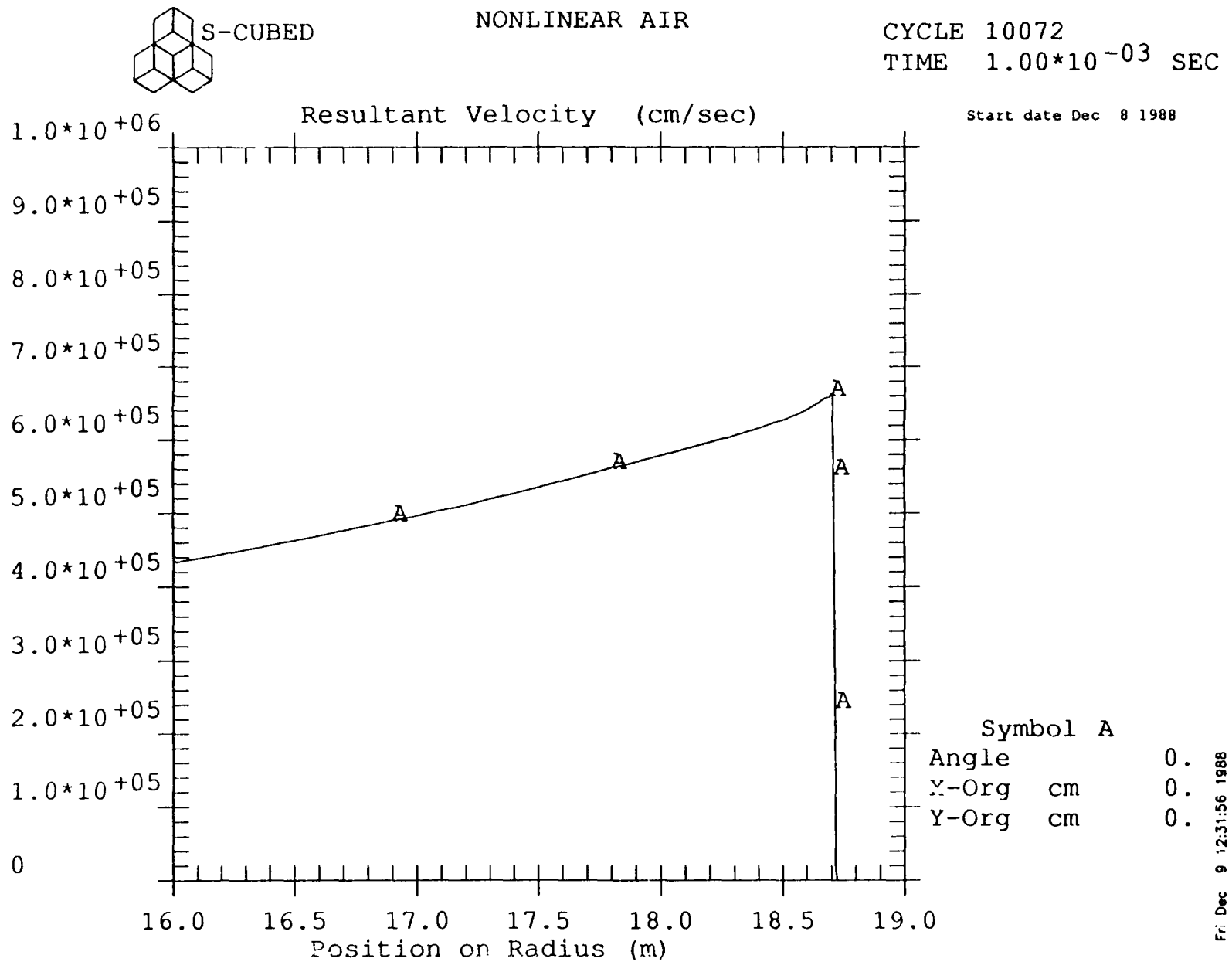

S-CUBED
NONLINEAR AIR
CYCLE 7404
TIME 4.00*10 -04 SEC
Start date Dec 8 1988
Pressure (Dynes/cm2)
2.0*10 +09
1.8*10 +09
1.6*10 +09
1.4*10 +09
1.2*10 +09
1.0*10 +09
8.0*10 +08
6.0*10 +08
4.0*10 +08
2.0*10 +08
0
Ambient 1.00*10 +06
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:27:50 1988


S-CUBED
NONLINEAR AIR
CYCLE 7404
TIME 4.00*10^-04 SEC
Start date Dec 8 1988
Matter Density (G/cm3)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:28:00 1988

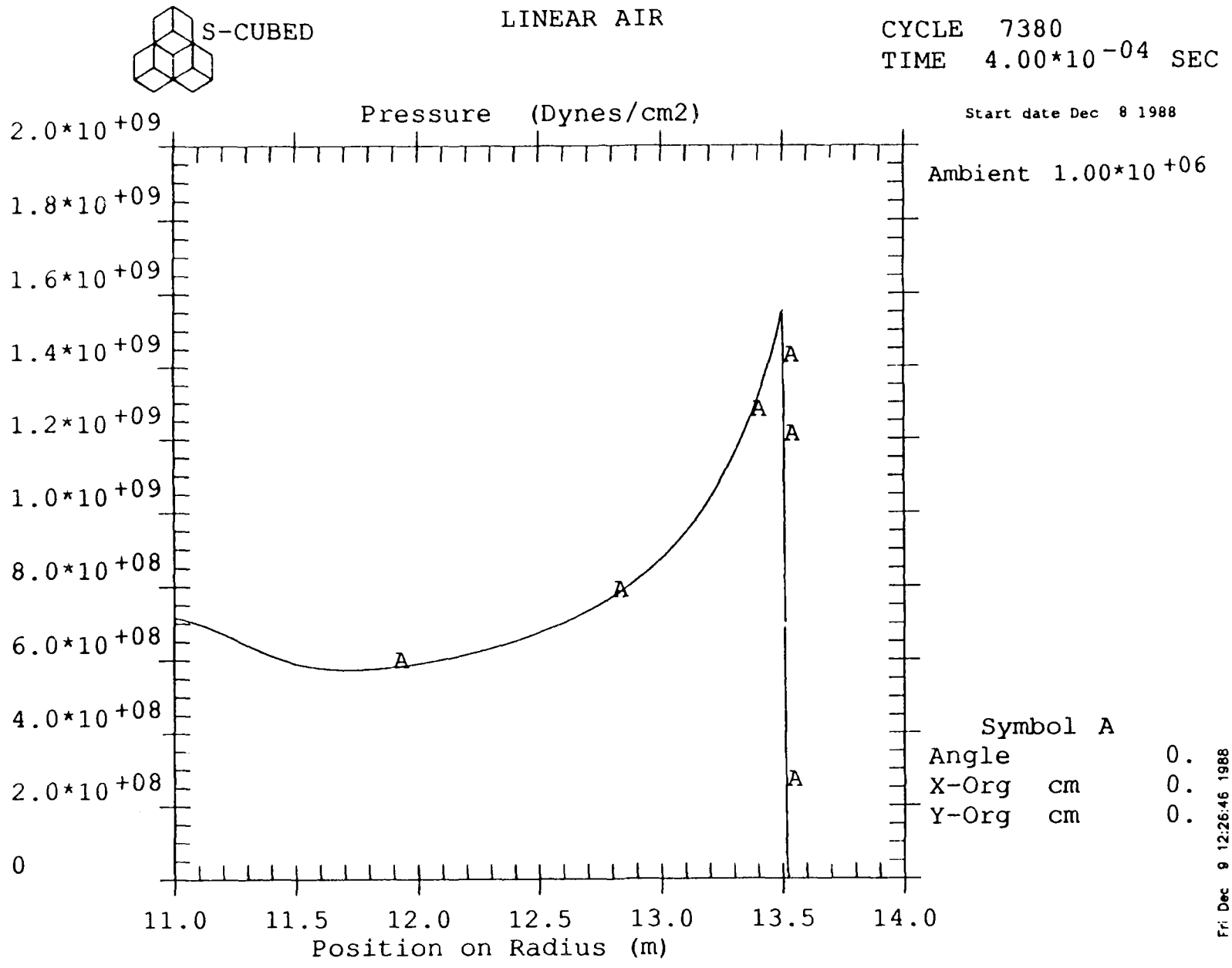

S-CUBED
NONLINEAR AIR
CYCLE 7404
TIME 4.00*10-04 SEC
Start date Dec 8 1988
Resultant Velocity (cm/sec)
2.0*10+06
1.8*10+06
1.6*10+06
1.4*10+06
1.2*10+06
1.0*10+06
8.0*10+05
6.0*10+05
4.0*10+05
2.0*10+05
0
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:28:13 1988

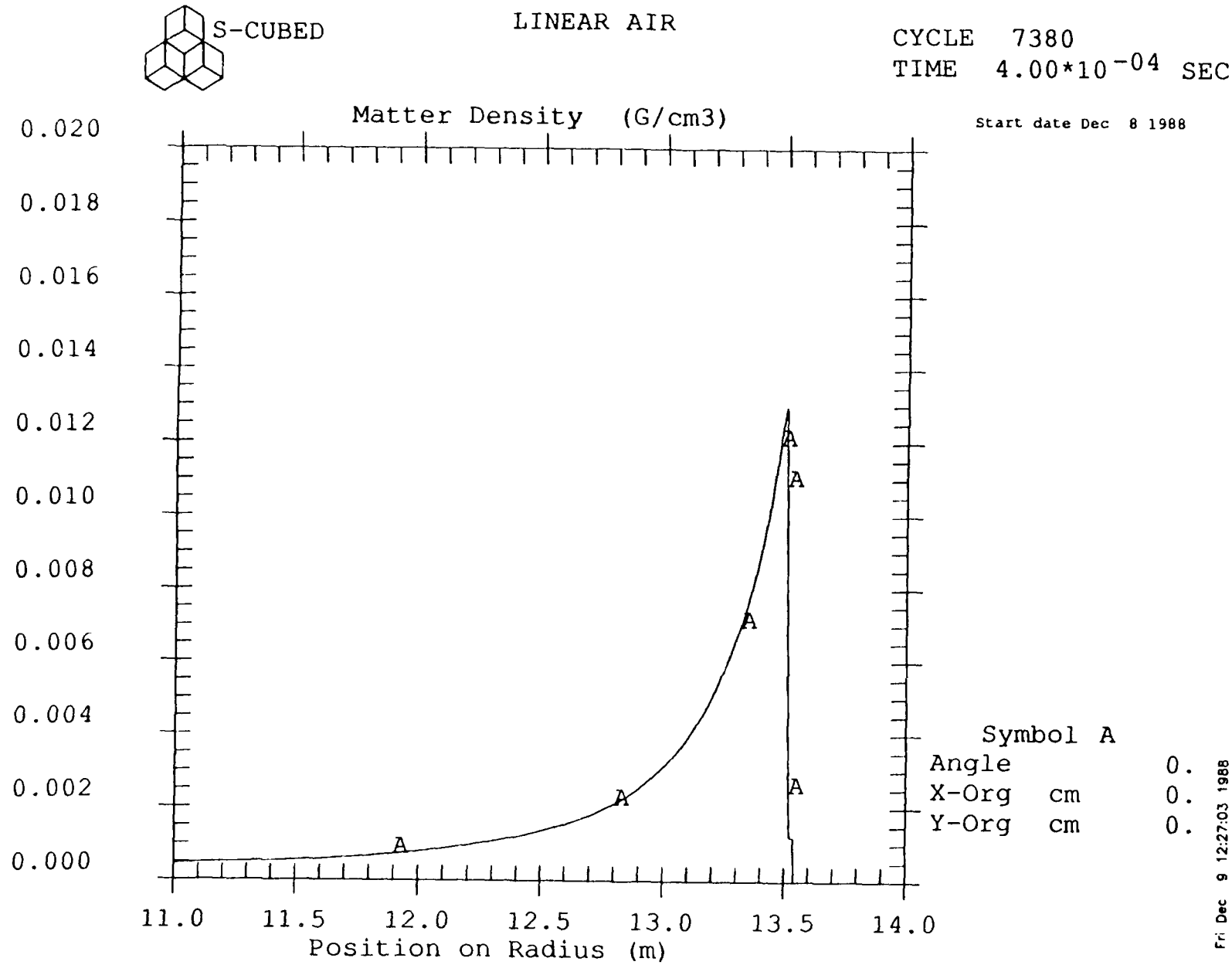

S-CUBED
NONLINEAR AIR
CYCLE 10072
TIME 1.00*10 -03 SEC
Start date Dec 8 1988
Pressure (Dynes/cm2)
Ambient 1.00*10 +06
1.0*10 +09
9.0*10 +08
8.0*10 +08
7.0*10 +08
6.0*10 +08
5.0*10 +08
4.0*10 +08
3.0*10 +08
2.0*10 +08
1.0*10 +08
0
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:31:27 1988

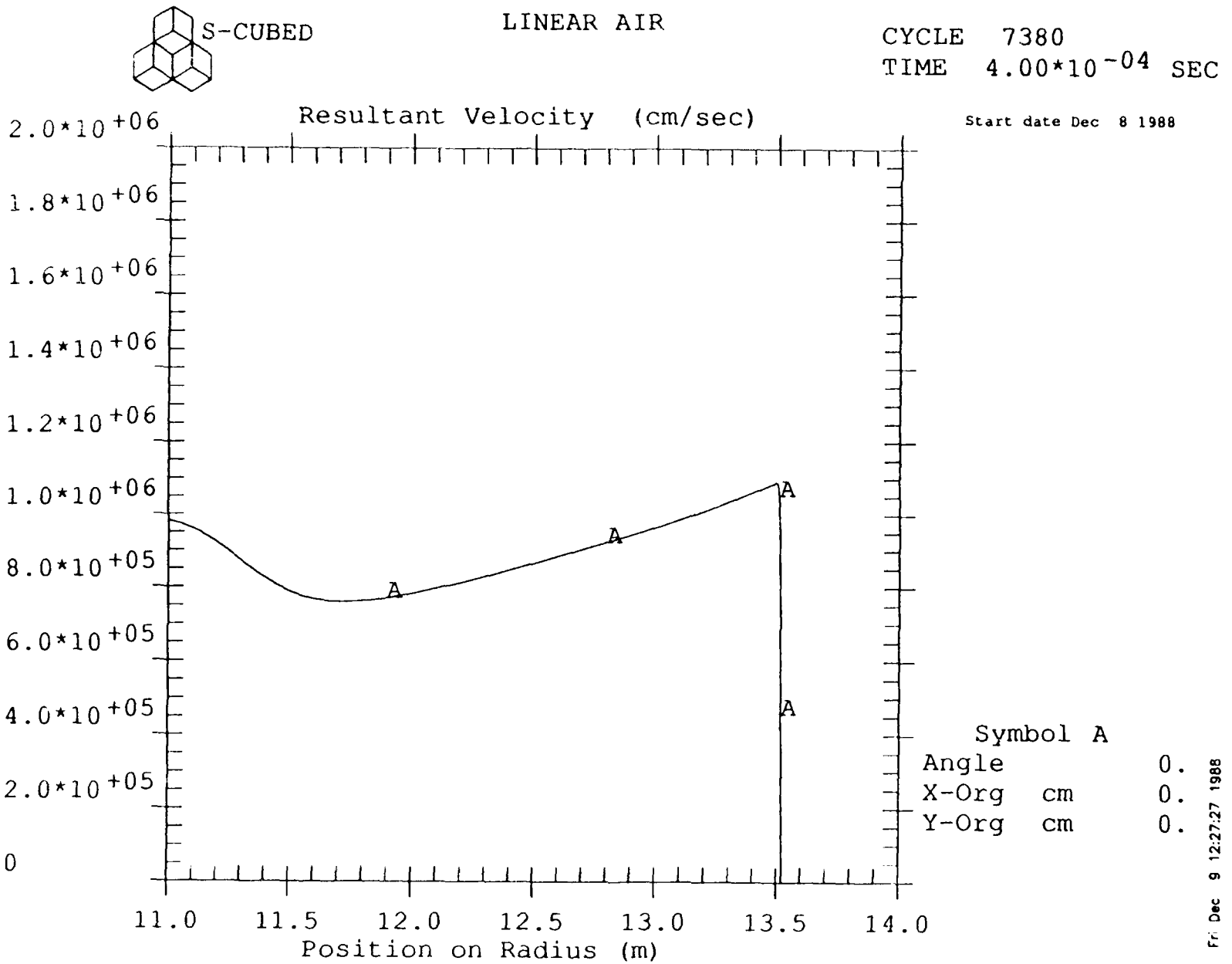

S-CUBED
NONLINEAR AIR
CYCLE 10072
TIME 1.00*10 -03 SEC
Start date Dec 8 1988
Matter Density (G/cm3)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:31:44 1988

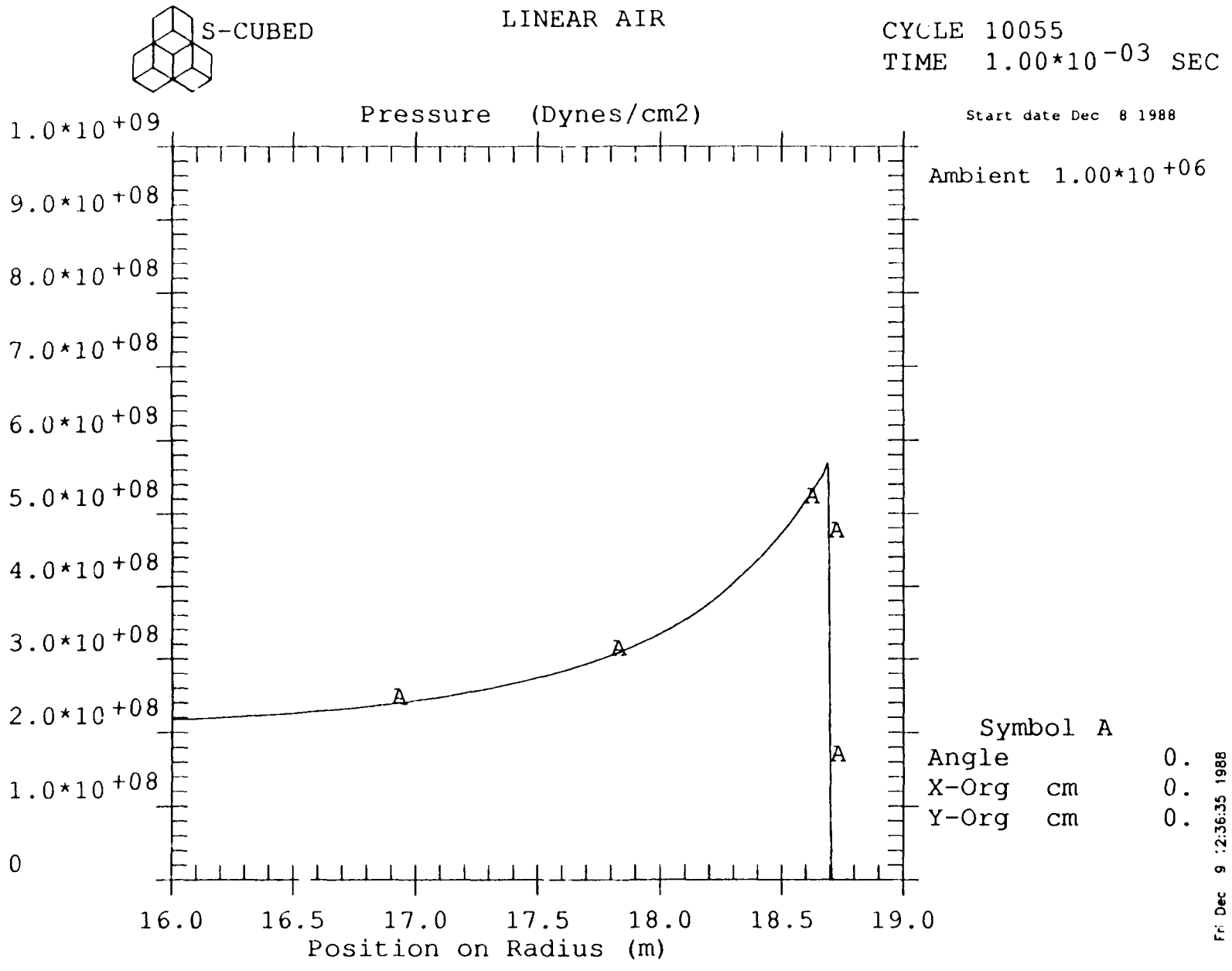

S-CUBED
NONLINEAR AIR
CYCLE 10072
TIME 1.00*10^-03 SEC
Start date Dec 8 1988
Resultant Velocity (cm/sec)
1.0*10^+06
9.0*10^+05
8.0*10^+05
7.0*10^+05
6.0*10^+05
5.0*10^+05
4.0*10^+05
3.0*10^+05
2.0*10^+05
1.0*10^+05
0
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:31:56 1988

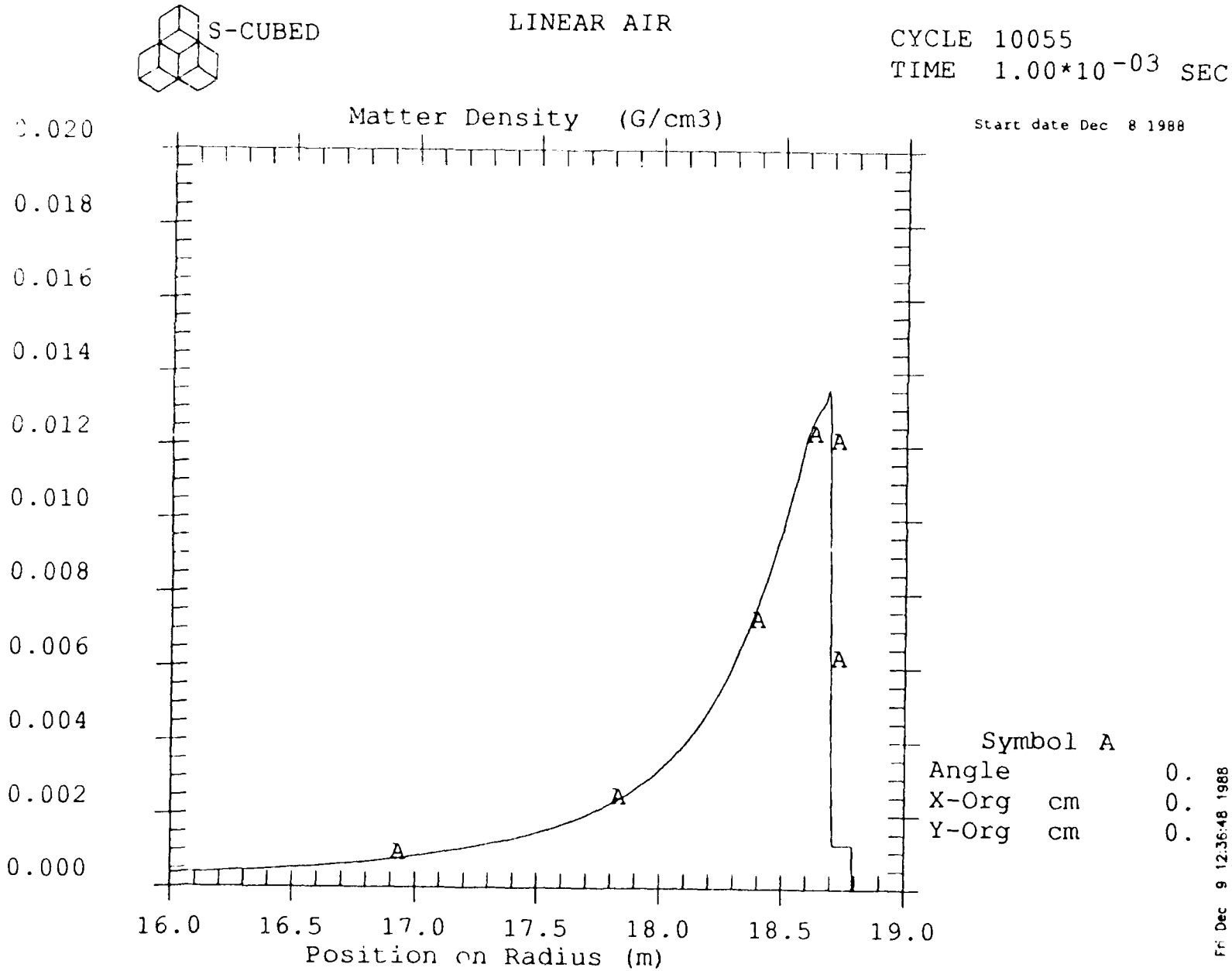
APPENDIX F
STREAK WITH $C_L = 0.5$
HIGH PRESSURE, FINE ZONING

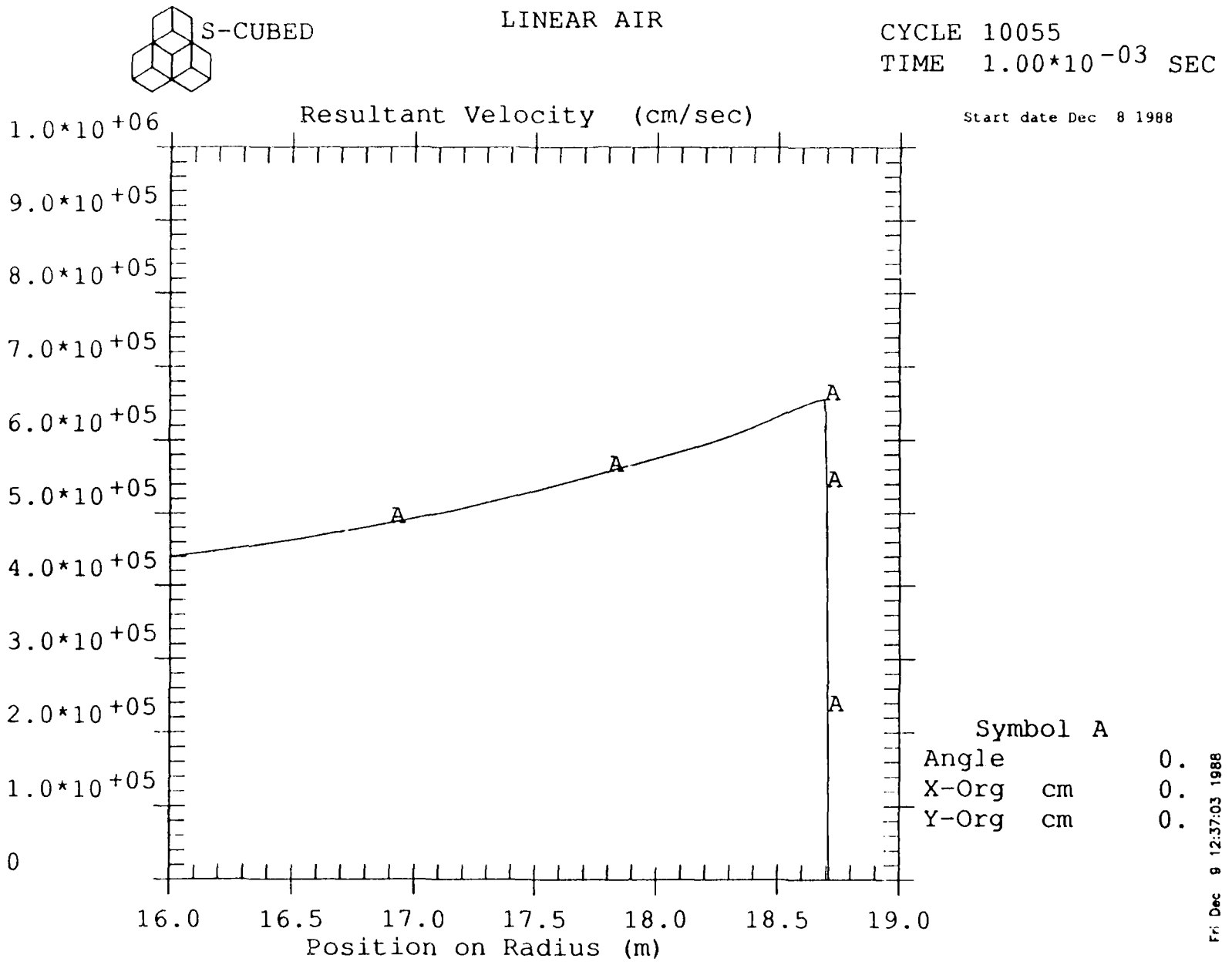

S-CUBED
LINEAR AIR
CYCLE 7380
TIME 4.00*10 -04 SEC
Pressure (Dynes/cm2)
Start date Dec 8 1988
Ambient 1.00*10 +06
2.0*10 +09
1.8*10 +09
1.6*10 +09
1.4*10 +09
1.2*10 +09
1.0*10 +09
8.0*10 +08
6.0*10 +08
4.0*10 +08
2.0*10 +08
0
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:26:46 1988


S-CUBED
LINEAR AIR
CYCLE 7380
TIME 4.00*10^-04 SEC
Start date Dec 8 1988
Matter Density (G/cm3)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:27:03 1988

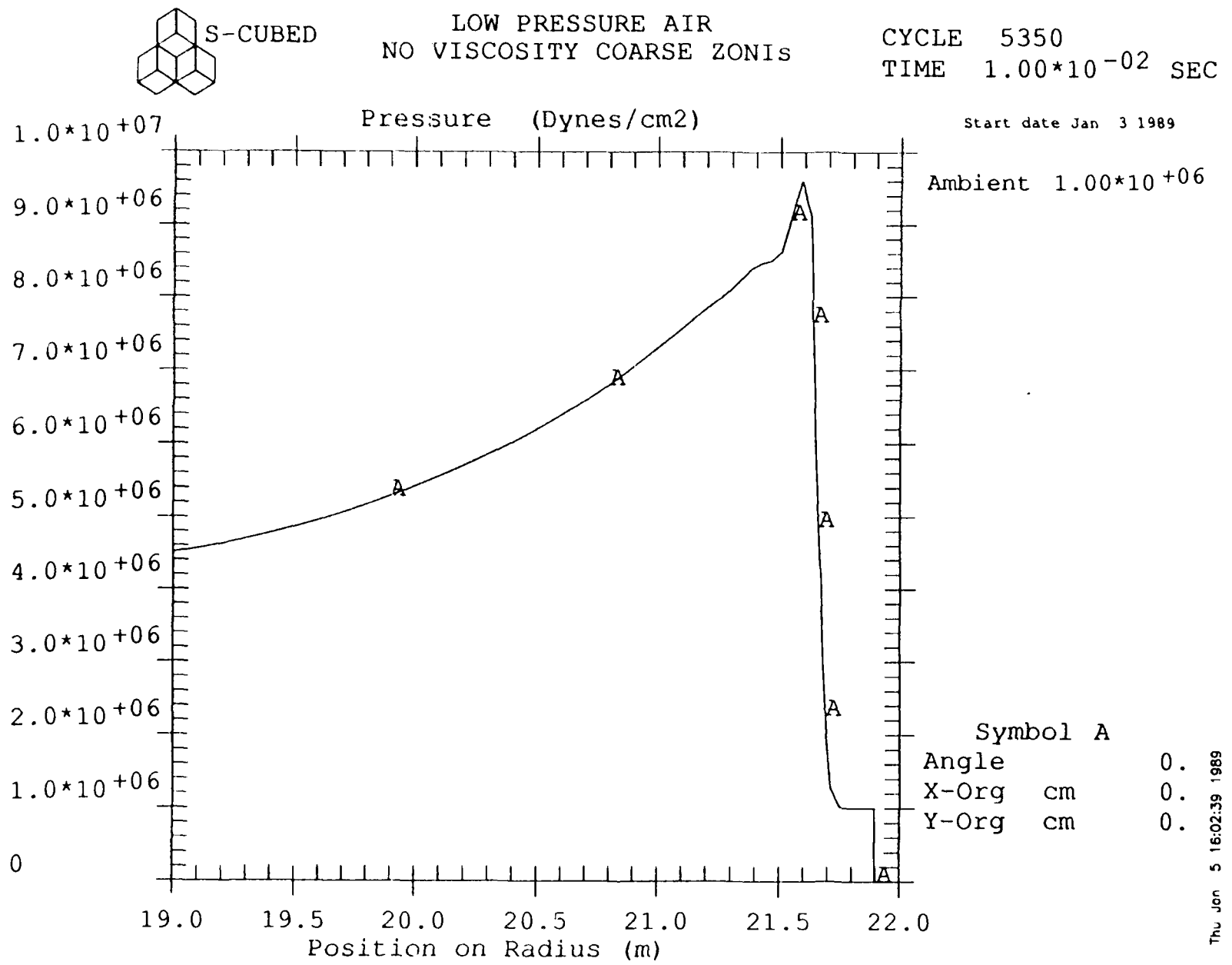

S-CUBED
LINEAR AIR
CYCLE 7380
TIME 4.00*10^-04 SEC
Start date Dec 8 1988
Resultant Velocity (cm/sec)
2.0*10^+06
1.8*10^+06
1.6*10^+06
1.4*10^+06
1.2*10^+06
1.0*10^+06
8.0*10^+05
6.0*10^+05
4.0*10^+05
2.0*10^+05
0
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Position on Radius (m)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:27:27 1988

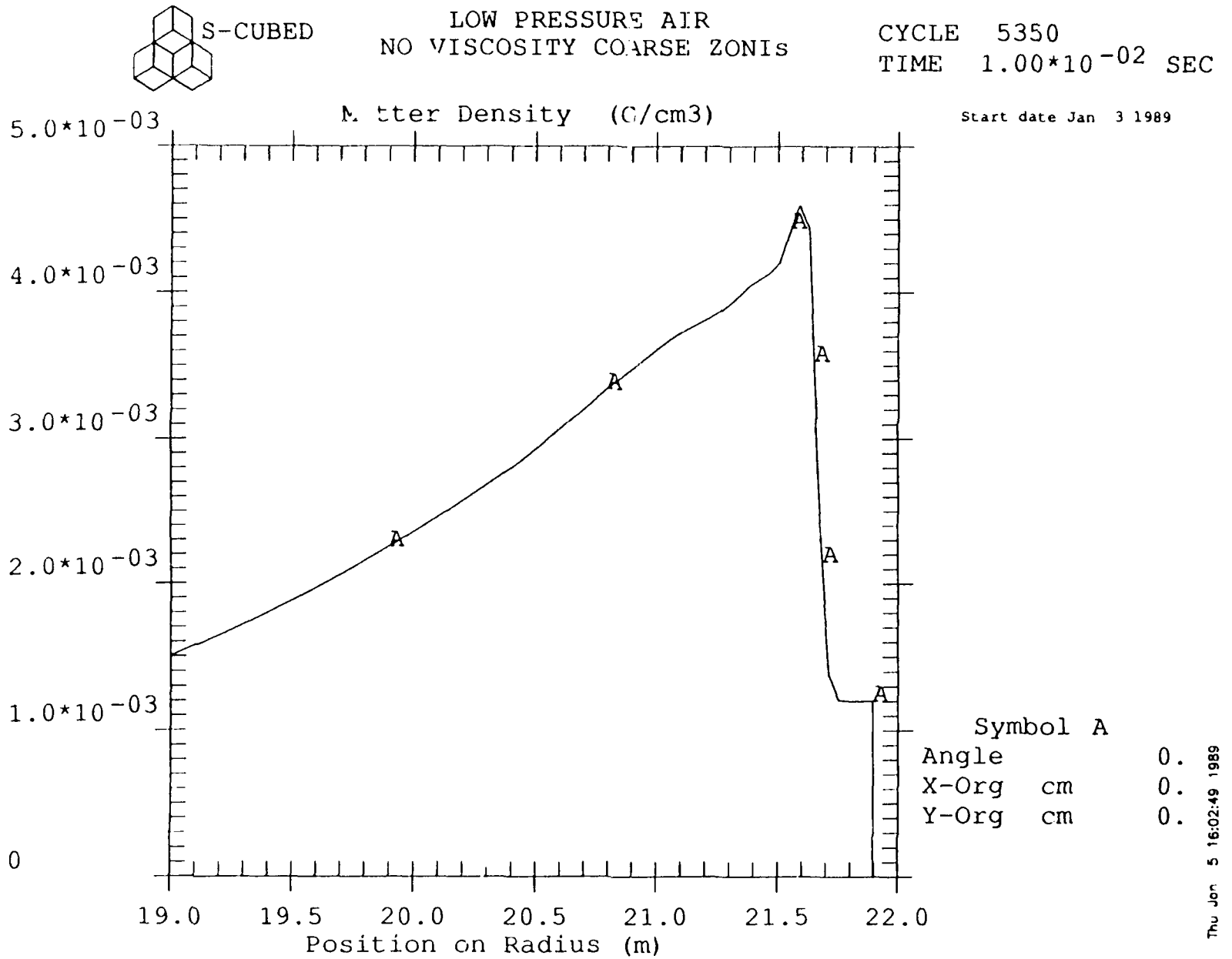

S-CUBED
LINEAR AIR
CYCLE 10055
TIME 1.00*10 -03 SEC
Pressure (Dynes/cm2)
Start date Dec 8 1988
Ambient 1.00*10 +06
1.0*10 +09
9.0*10 +08
8.0*10 +08
7.0*10 +08
6.0*10 +08
5.0*10 +08
4.0*10 +08
3.0*10 +08
2.0*10 +08
1.0*10 +08
0
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:36:35 1988

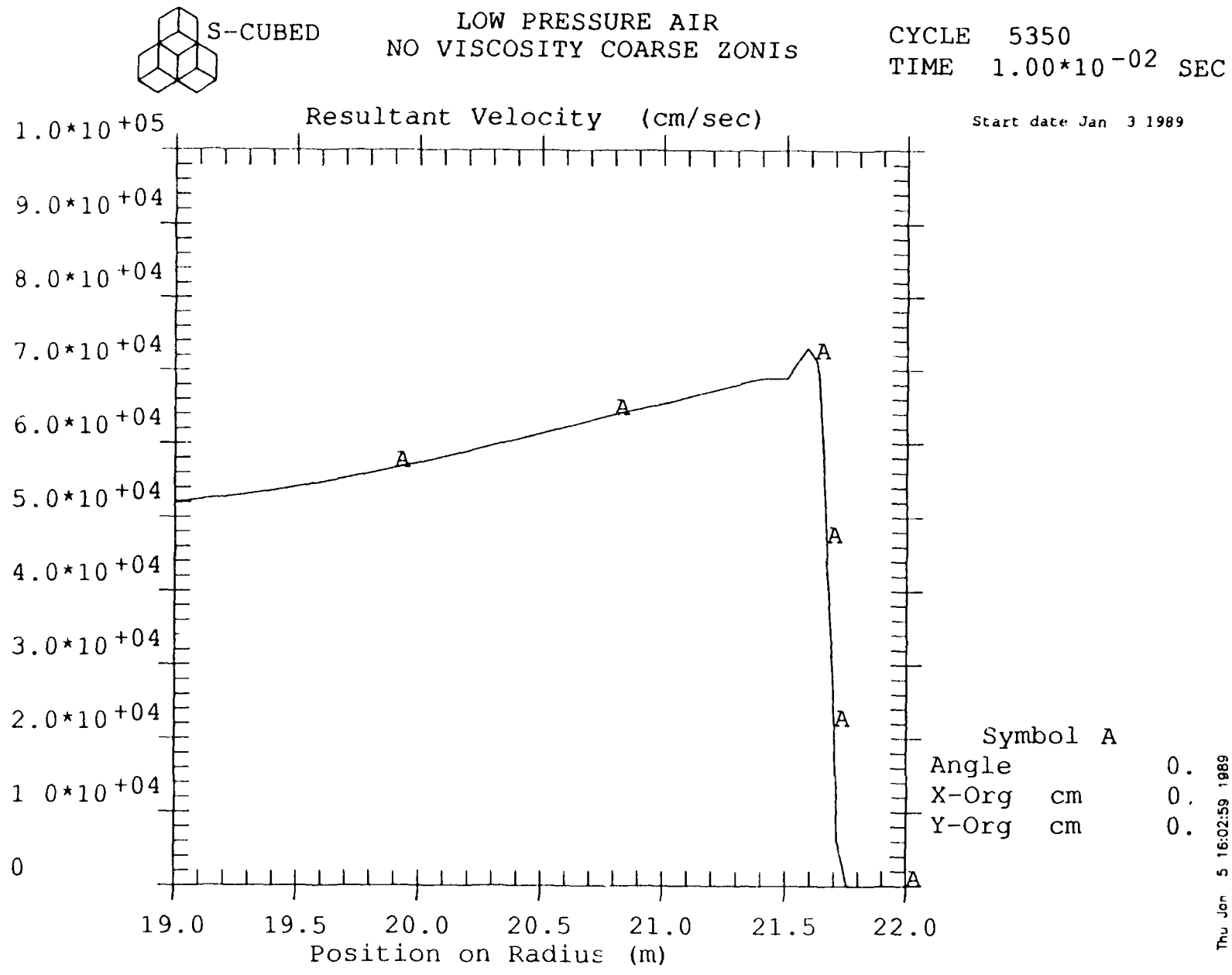

S-CUBED
LINEAR AIR
CYCLE 10055
TIME 1.00*10^-03 SEC
Start date Dec 8 1988
Matter Density (G/cm3)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:36:48 1988

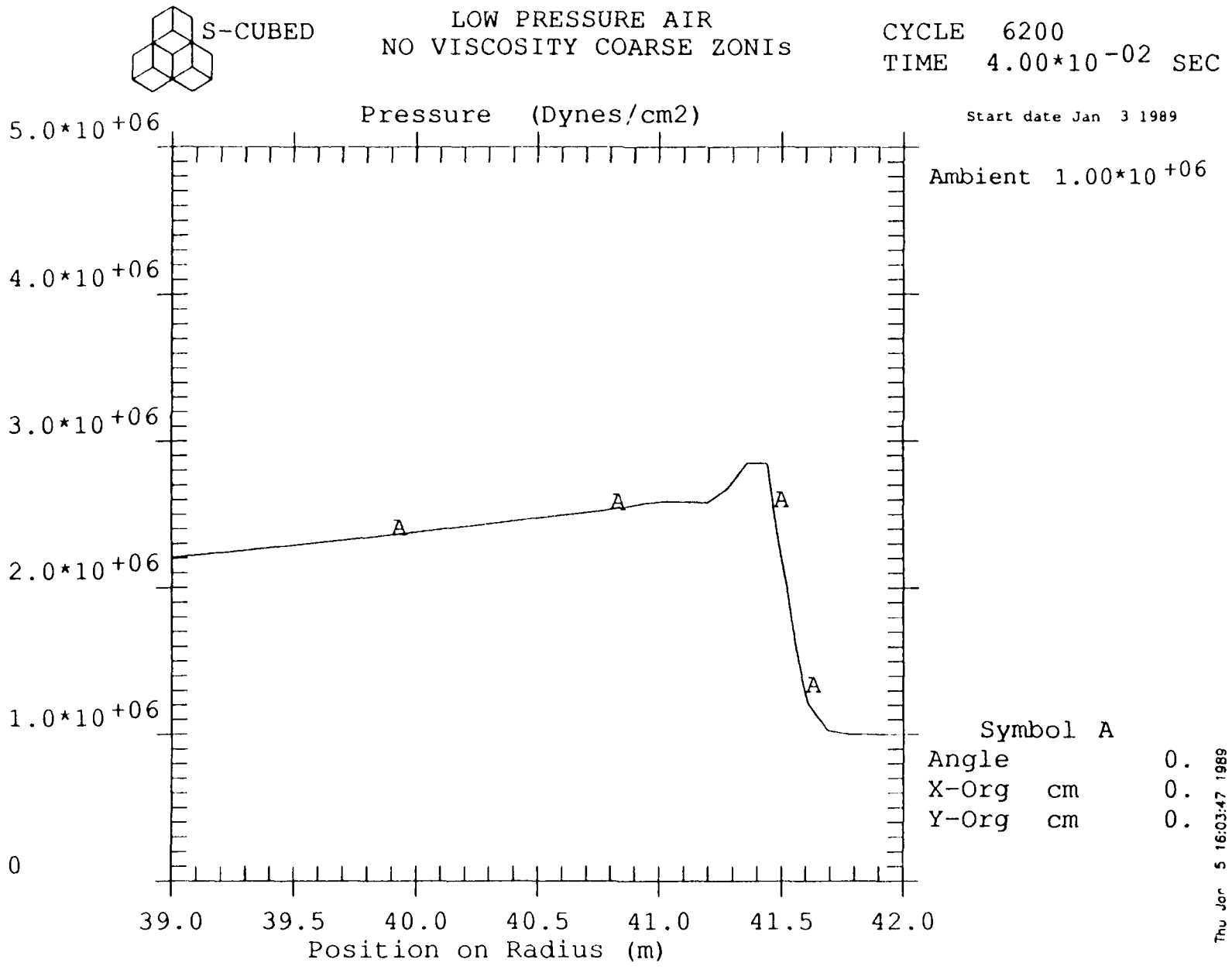

S-CUBED
LINEAR AIR
CYCLE 10055
TIME 1.00*10-03 SEC
Resultant Velocity (cm/sec)
Start date Dec 8 1988
1.0*10+06
9.0*10+05
8.0*10+05
7.0*10+05
6.0*10+05
5.0*10+05
4.0*10+05
3.0*10+05
2.0*10+05
1.0*10+05
0
16.0
16.5
17.0
17.5
18.0
18.5
19.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 9 12:37:03 1988

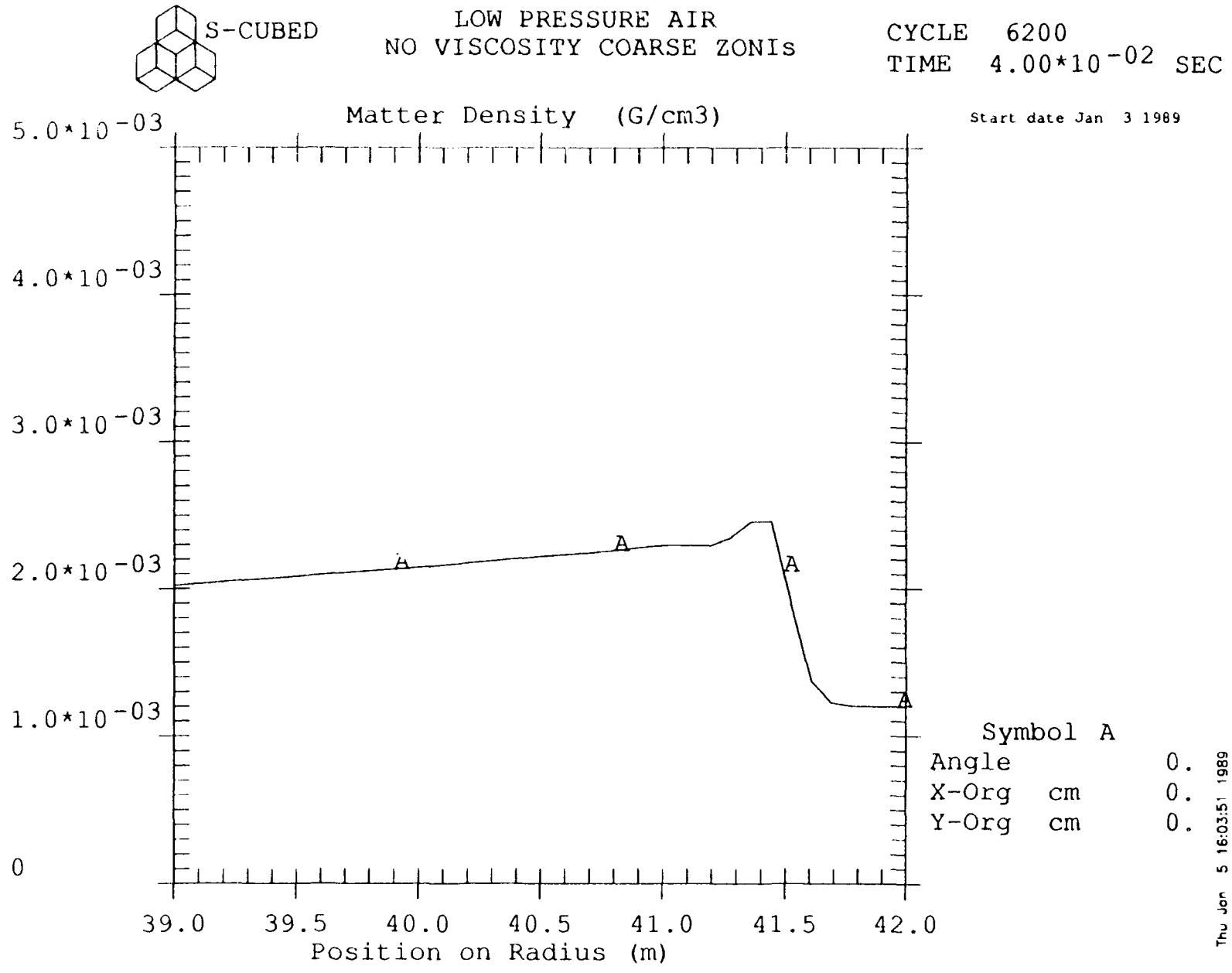
APPENDIX G
STANDARD STREAK
LOW PRESSURE, COARSE ZONING

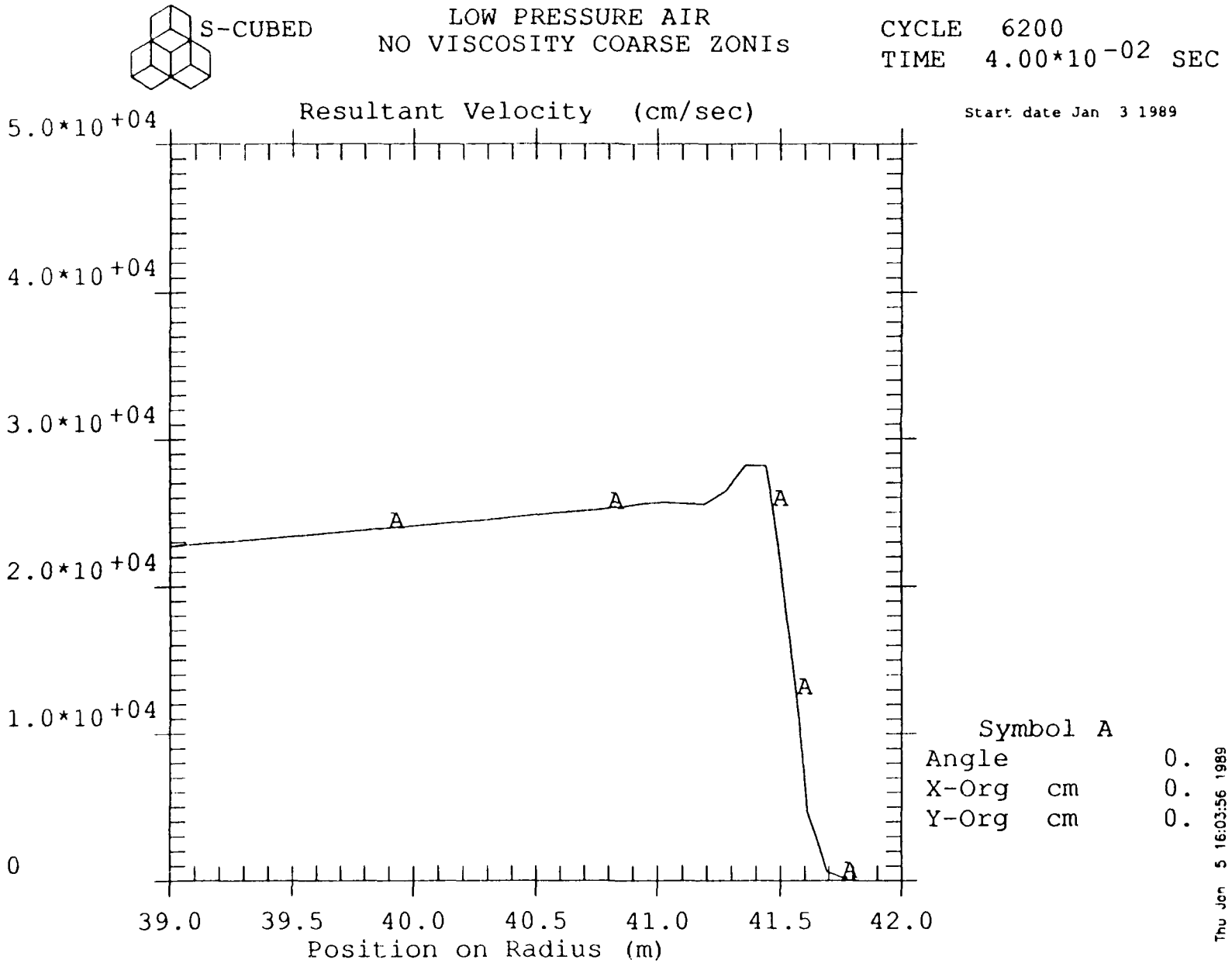

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 5350
TIME 1.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Jan 3 1989
Ambient 1.00*10 +06
1.0*10 +07
9.0*10 +06
8.0*10 +06
7.0*10 +06
6.0*10 +06
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:02:39 1989

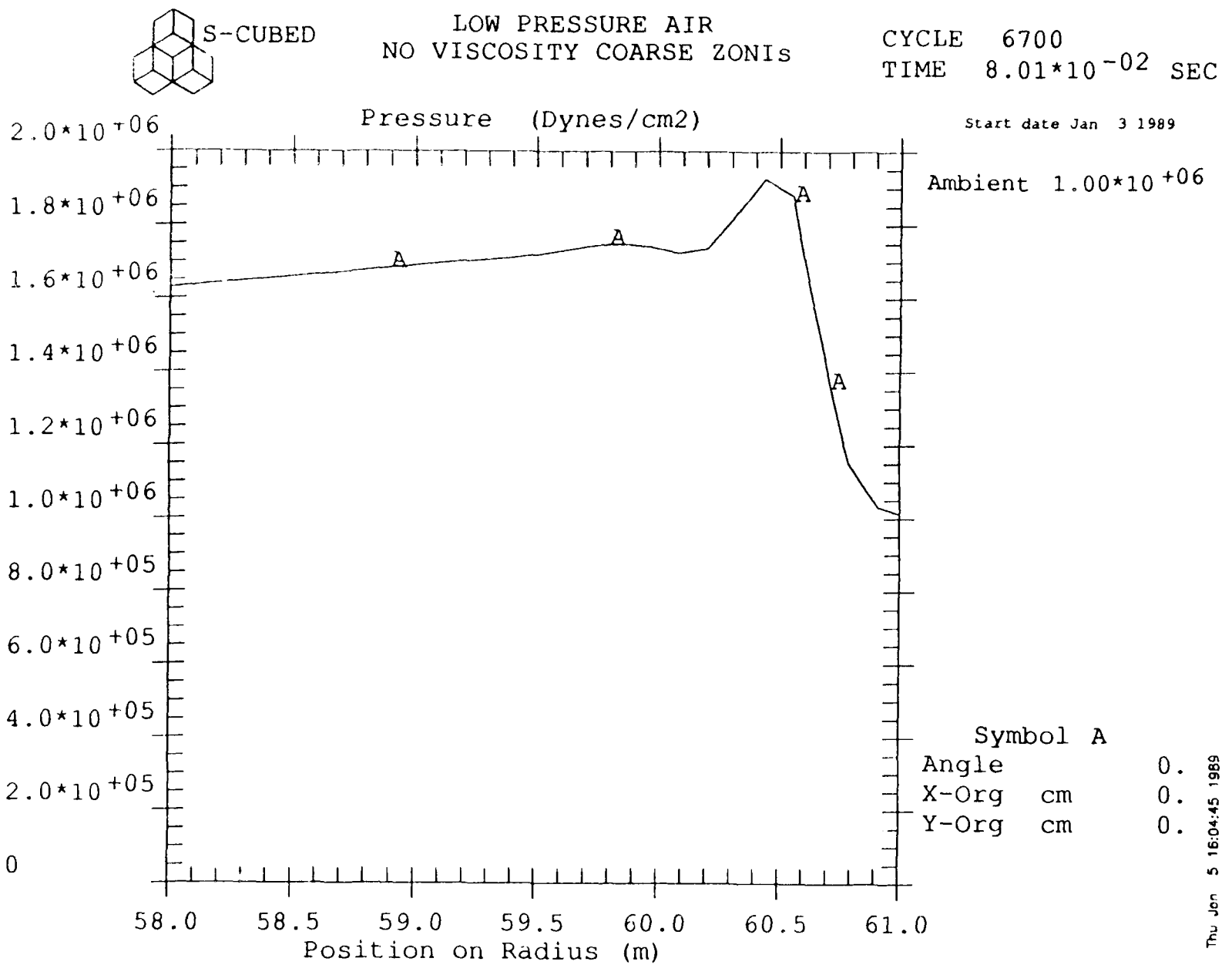

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 5350
TIME 1.00*10-02 SEC
Start date Jan 3 1989
M tter Density (G/cm3)
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:02:49 1989

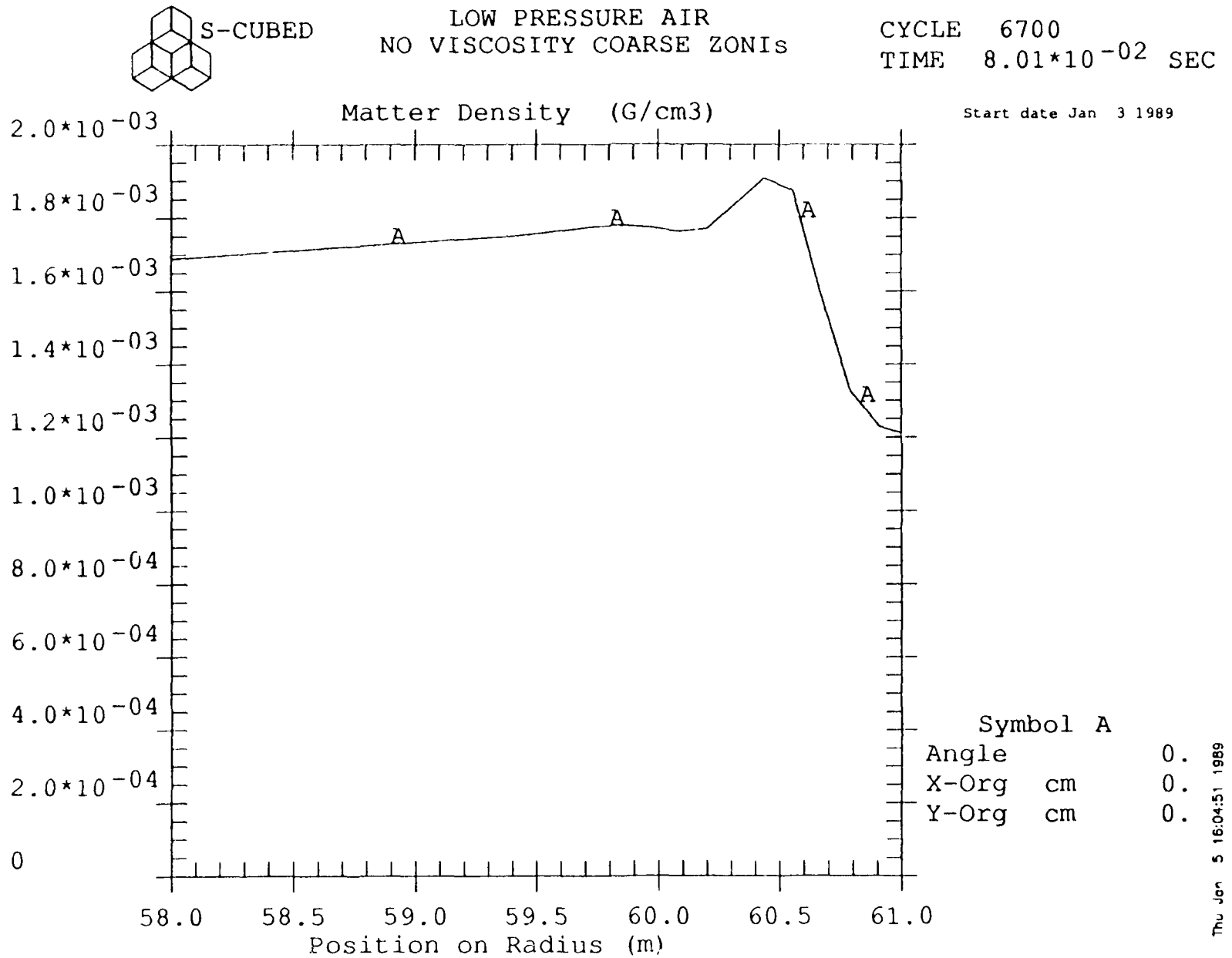

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 5350
TIME 1.00*10 -02 SEC
Start date Jan 3 1989
Resultant Velocity (cm/sec)
1.0*10 +05
9.0*10 +04
8.0*10 +04
7.0*10 +04
6.0*10 +04
5.0*10 +04
4.0*10 +04
3.0*10 +04
2.0*10 +04
1 0*10 +04
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:02:59 1989

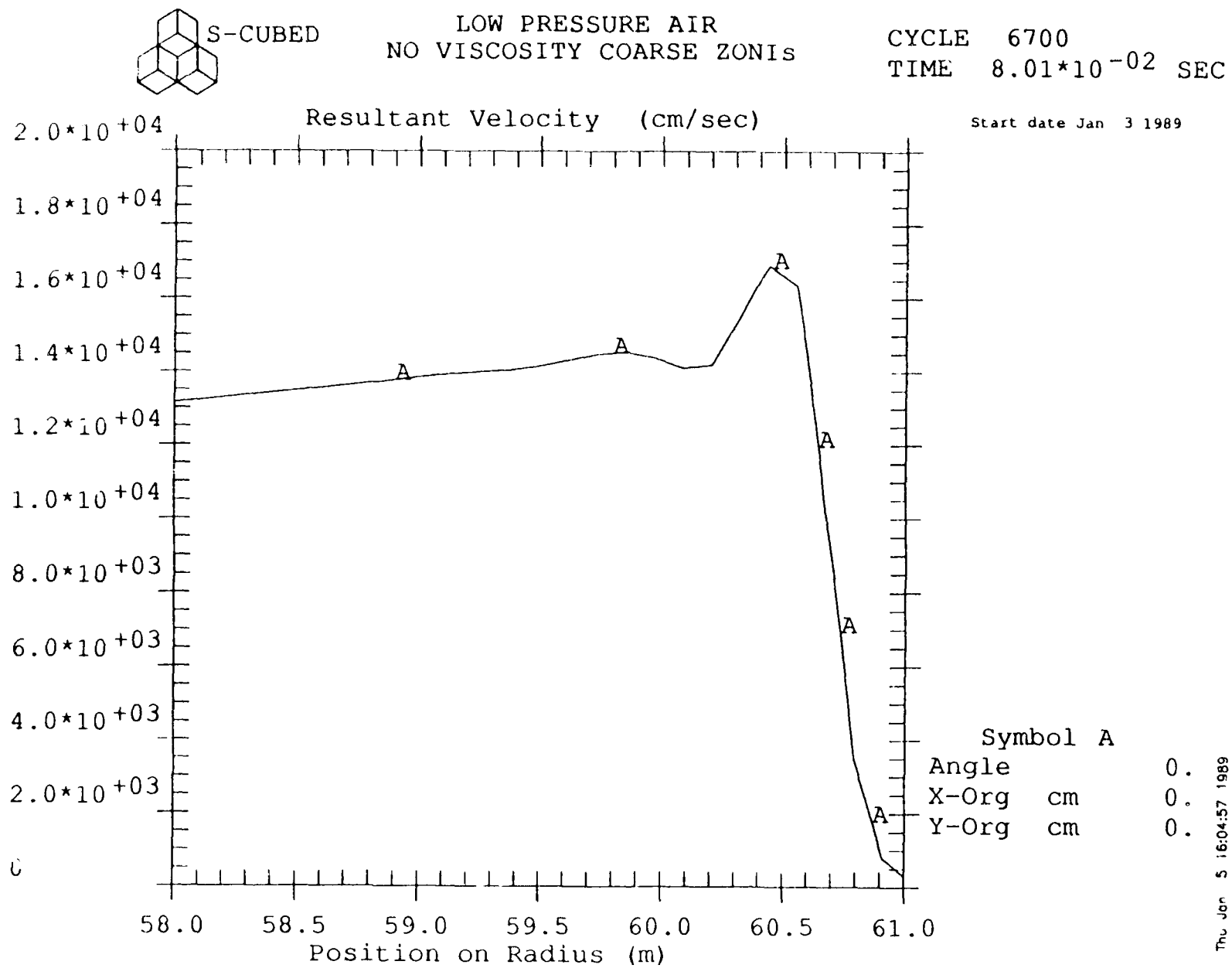

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6200
TIME 4.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Jan 3 1989
Ambient 1.00*10 +06
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Thu Jan 5 16:03:47 1989

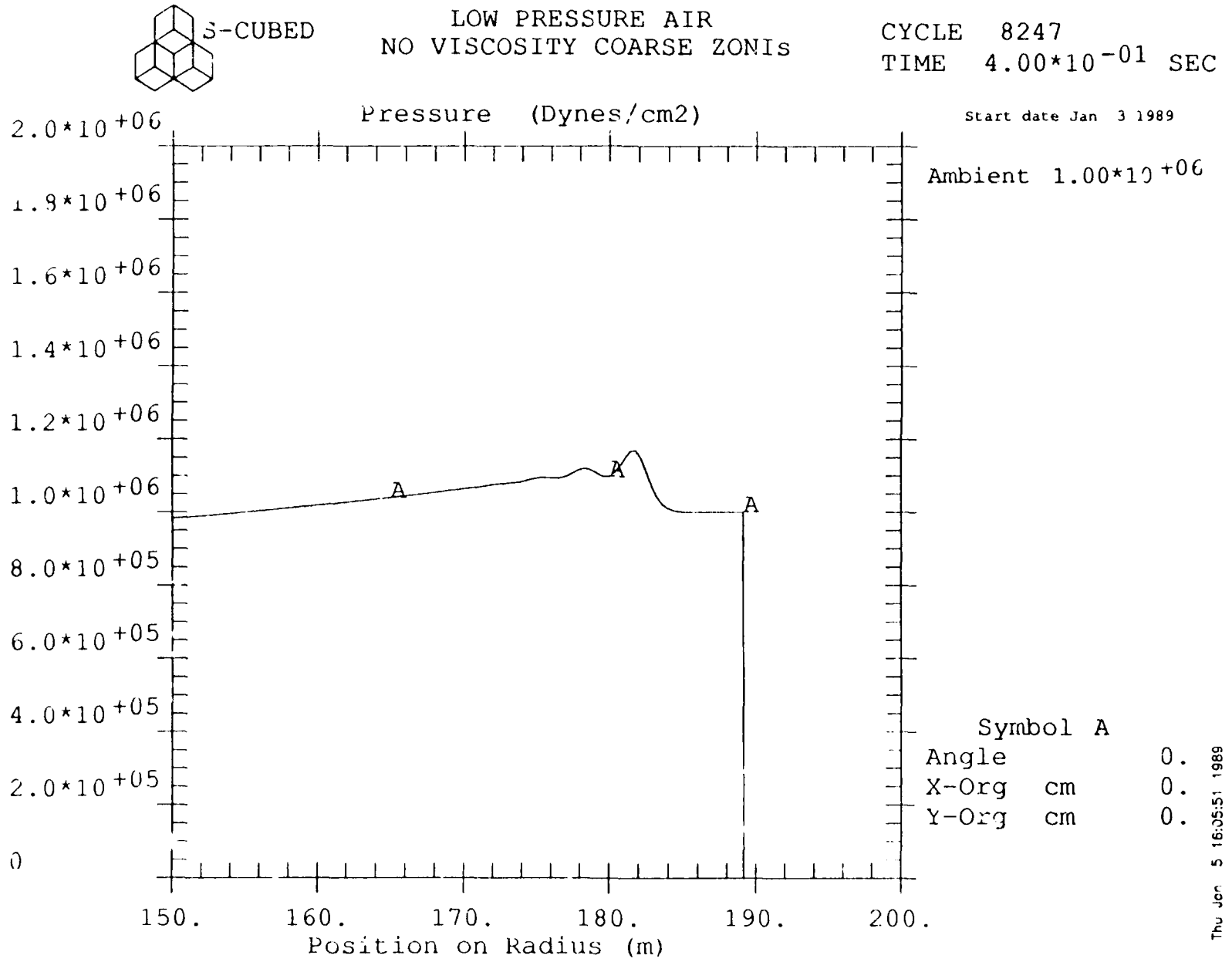

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6200
TIME 4.00*10-02 SEC
Matter Density (G/cm3)
Start date Jan 3 1989
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Thu Jan 5 16:03:51 1989

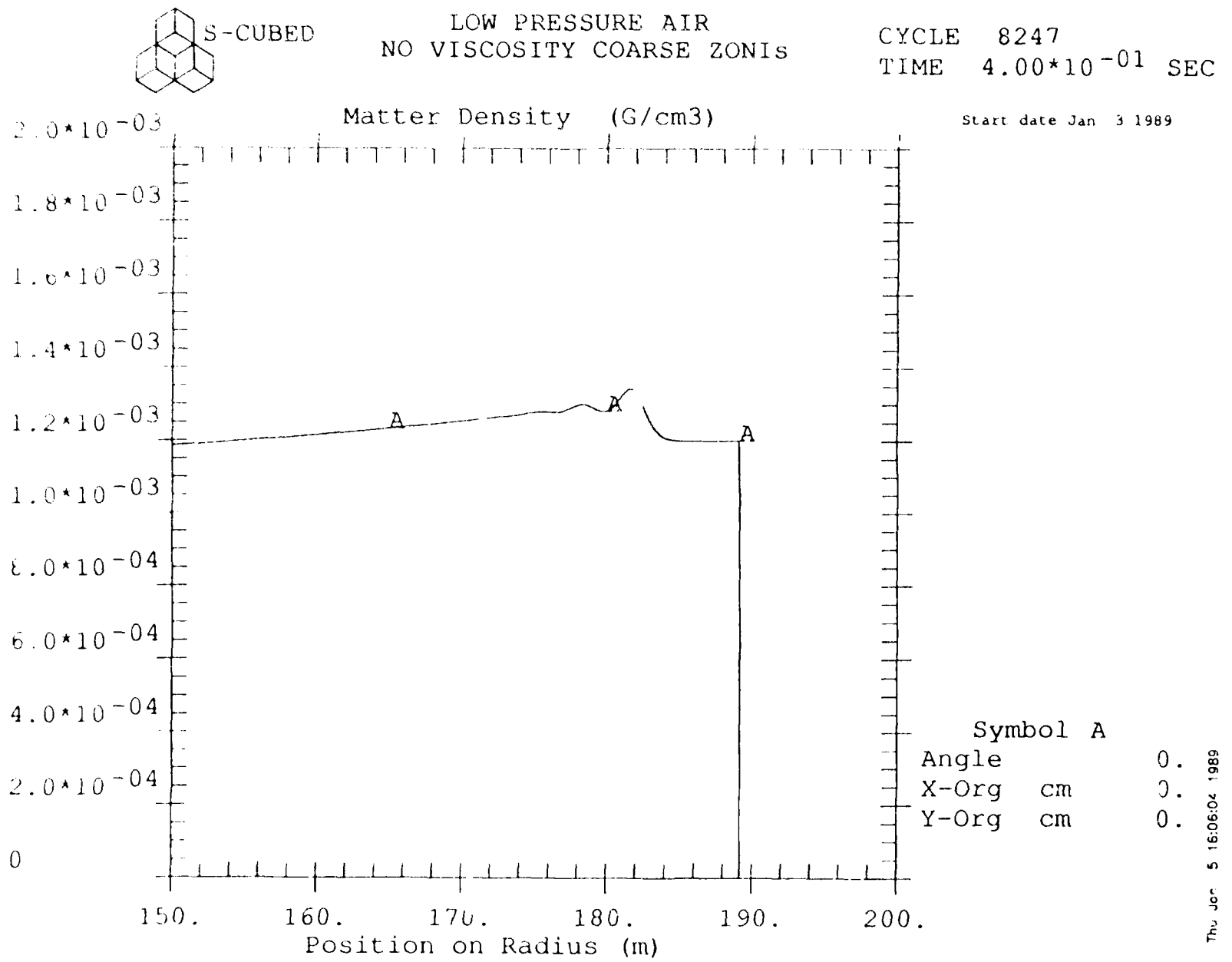

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6200
TIME 4.00*10-02 SEC
Resultant Velocity (cm/sec)
Start date Jan 3 1989
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:03:56 1989

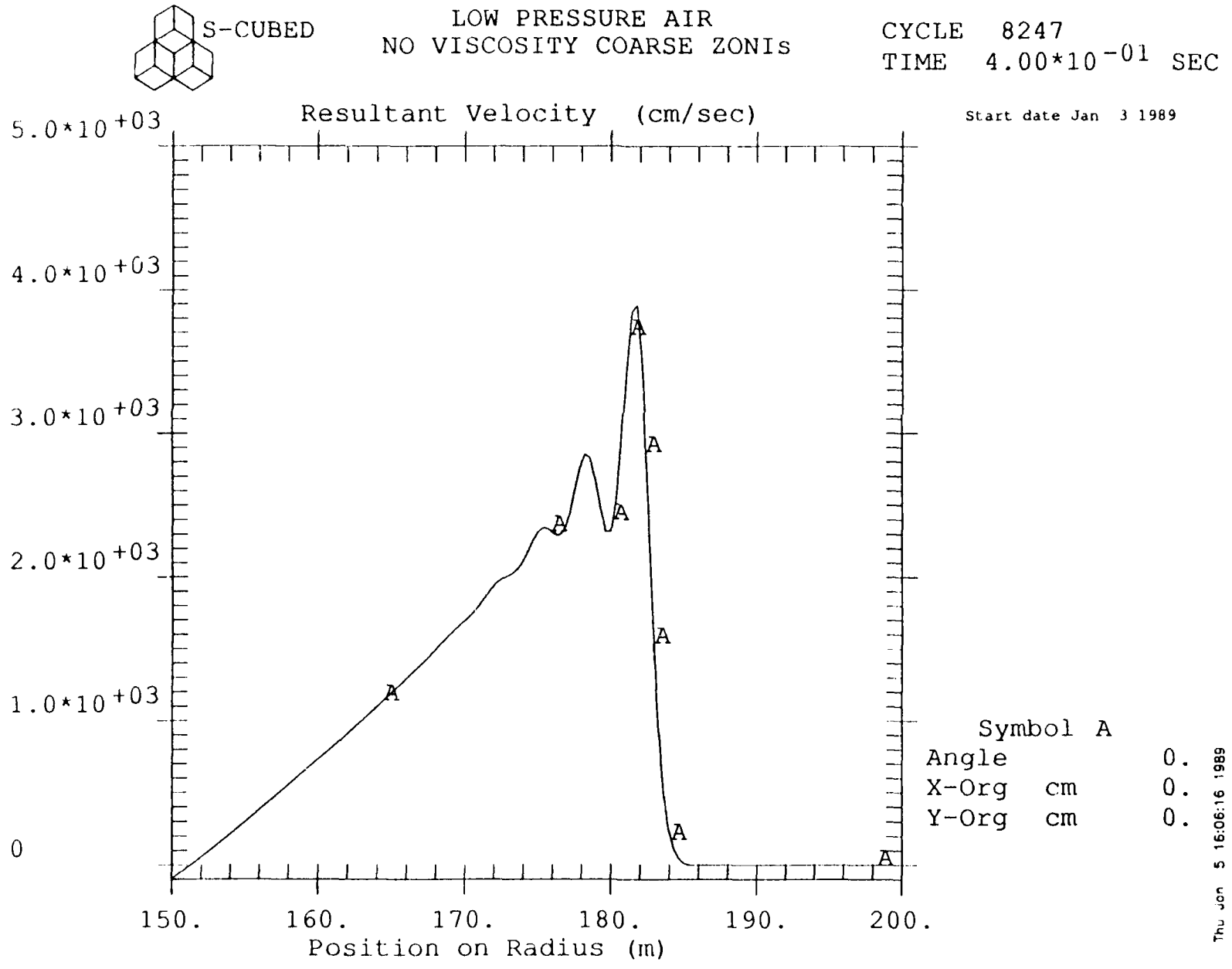

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6700
TIME 8.01*10 -02 SEC
Pressure (Dynes/cm2)
Start date Jan 3 1989
Ambient 1.00*10 +06
2.0*10 +06
1.8*10 +06
1.6*10 +06
1.4*10 +06
1.2*10 +06
1.0*10 +06
8.0*10 +05
6.0*10 +05
4.0*10 +05
2.0*10 +05
0
A
A
A
A
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:04:45 1989


S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6700
TIME 8.01*10-02 SEC
Start date Jan 3 1989
Matter Density (G/cm3)
2.0*10-03
1.8*10-03
1.6*10-03
1.4*10-03
1.2*10-03
1.0*10-03
8.0*10-04
6.0*10-04
4.0*10-04
2.0*10-04
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:04:51 1989

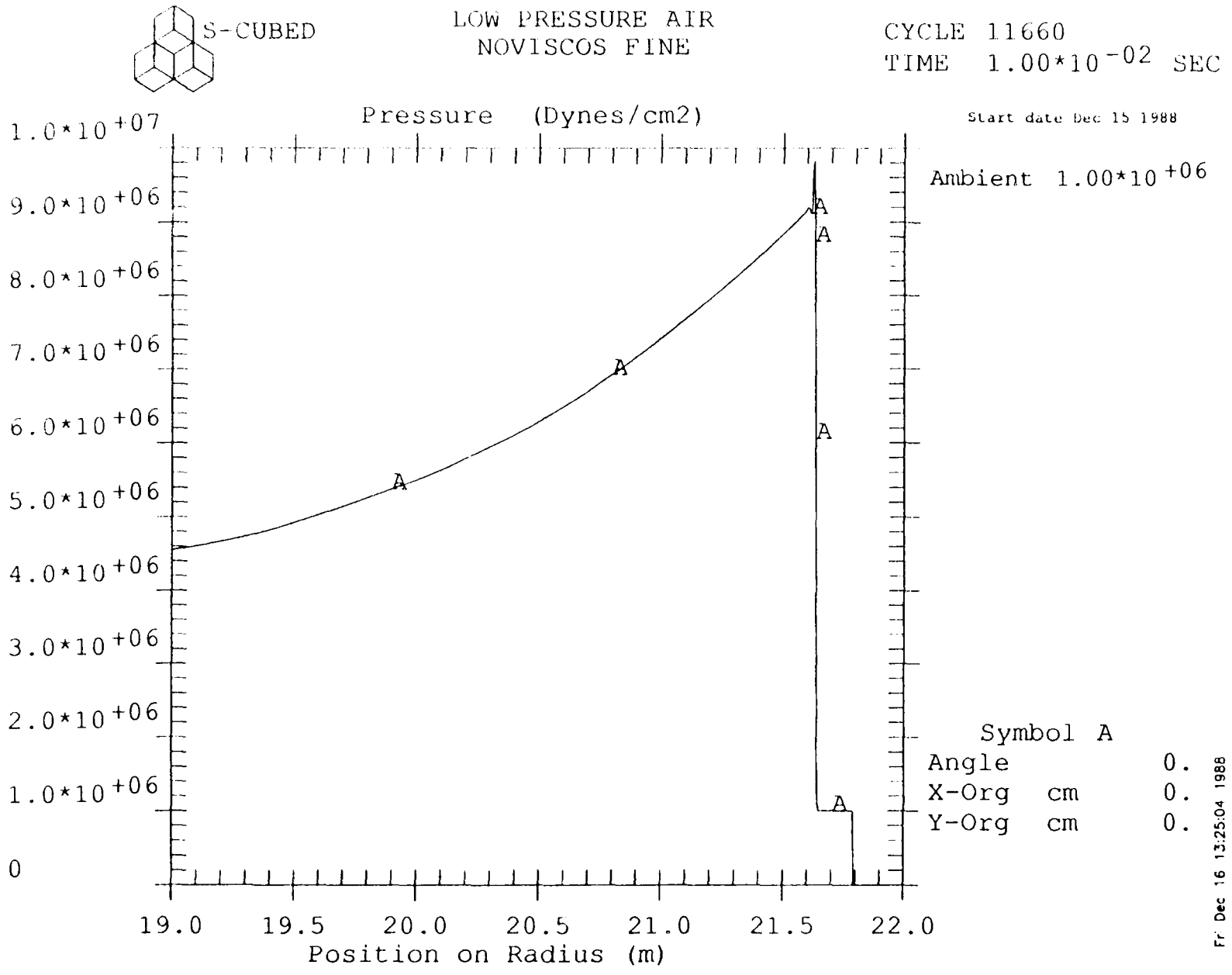

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 6700
TIME 8.01*10-02 SEC
Resultant Velocity (cm/sec)
Start date Jan 3 1989
2.0*10+04
1.8*10+04
1.6*10+04
1.4*10+04
1.2*10+04
1.0*10+04
8.0*10+03
6.0*10+03
4.0*10+03
2.0*10+03
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:04:57 1989

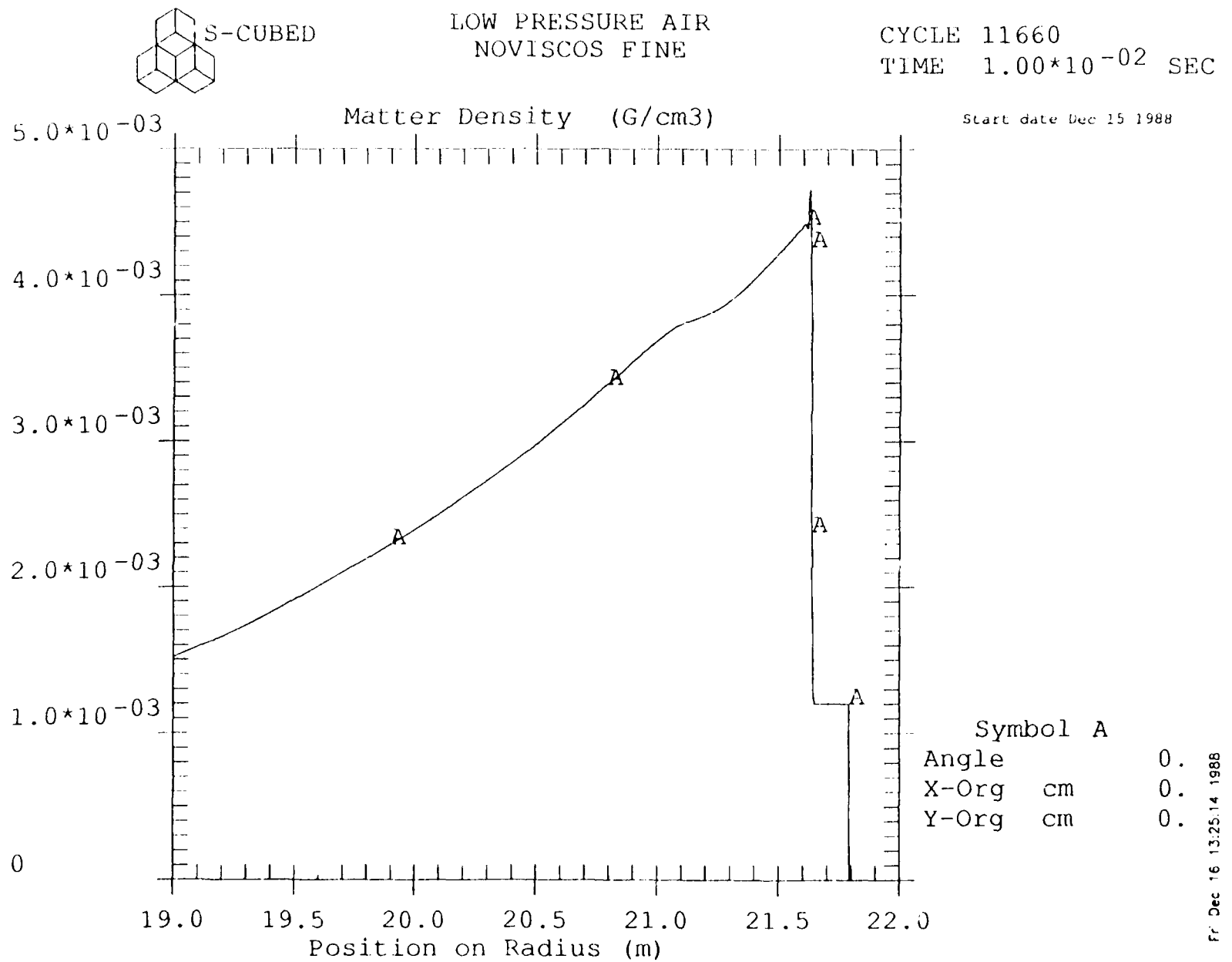

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 8247
TIME 4.00*10-01 SEC
Start date Jan 3 1989
Pressure (Dynes/cm2)
2.0*10+06
1.8*10+06
1.6*10+06
1.4*10+06
1.2*10+06
1.0*10+06
8.0*10+05
6.0*10+05
4.0*10+05
2.0*10+05
0
Ambient 1.00*10+06
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:05:51 1989

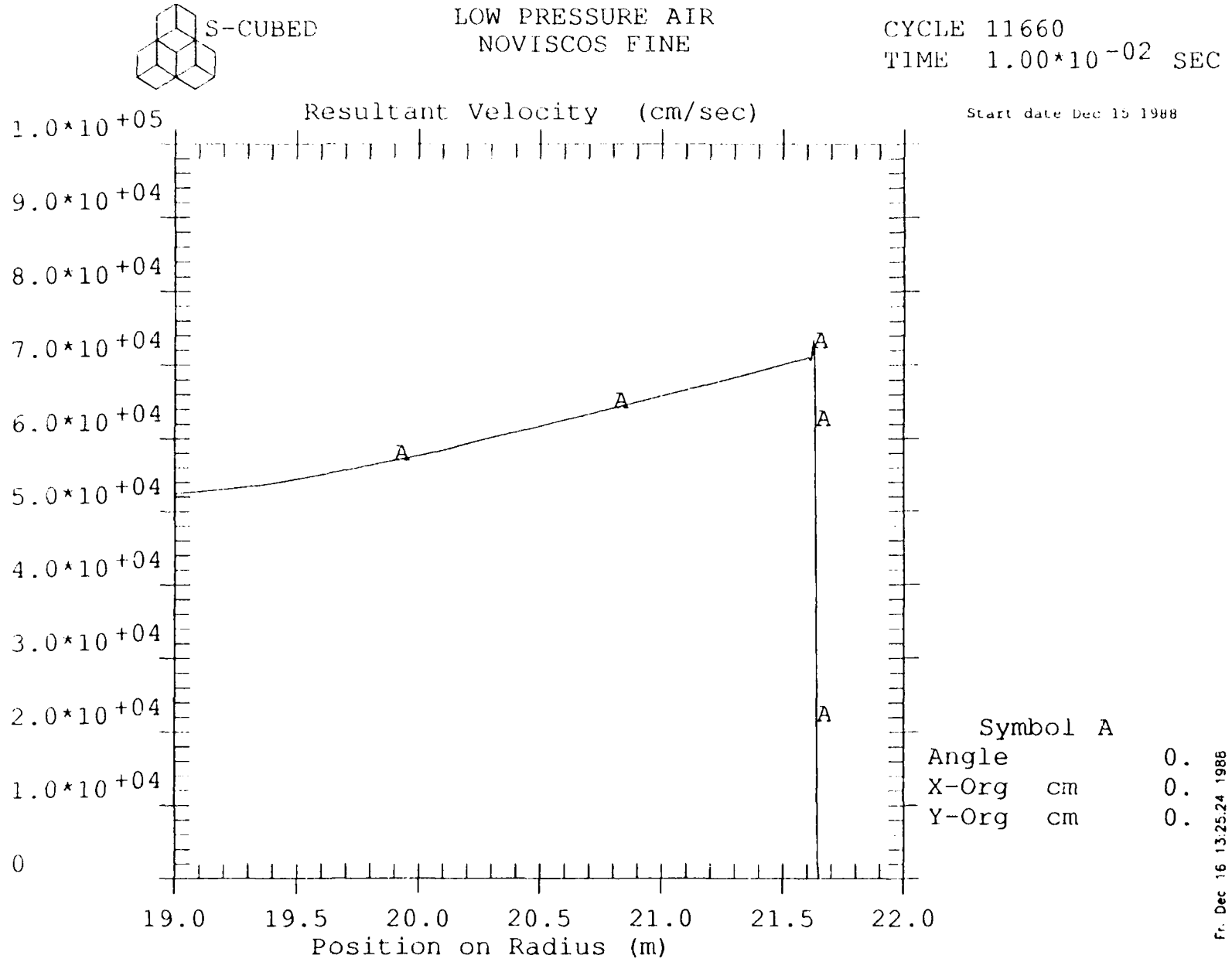

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 8247
TIME 4.00*10-01 SEC
Matter Density (G/cm3)
Start date Jan 3 1989
2.0*10-03
1.8*10-03
1.6*10-03
1.4*10-03
1.2*10-03
1.0*10-03
8.0*10-04
6.0*10-04
4.0*10-04
2.0*10-04
0
A
A
A
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:06:04 1989

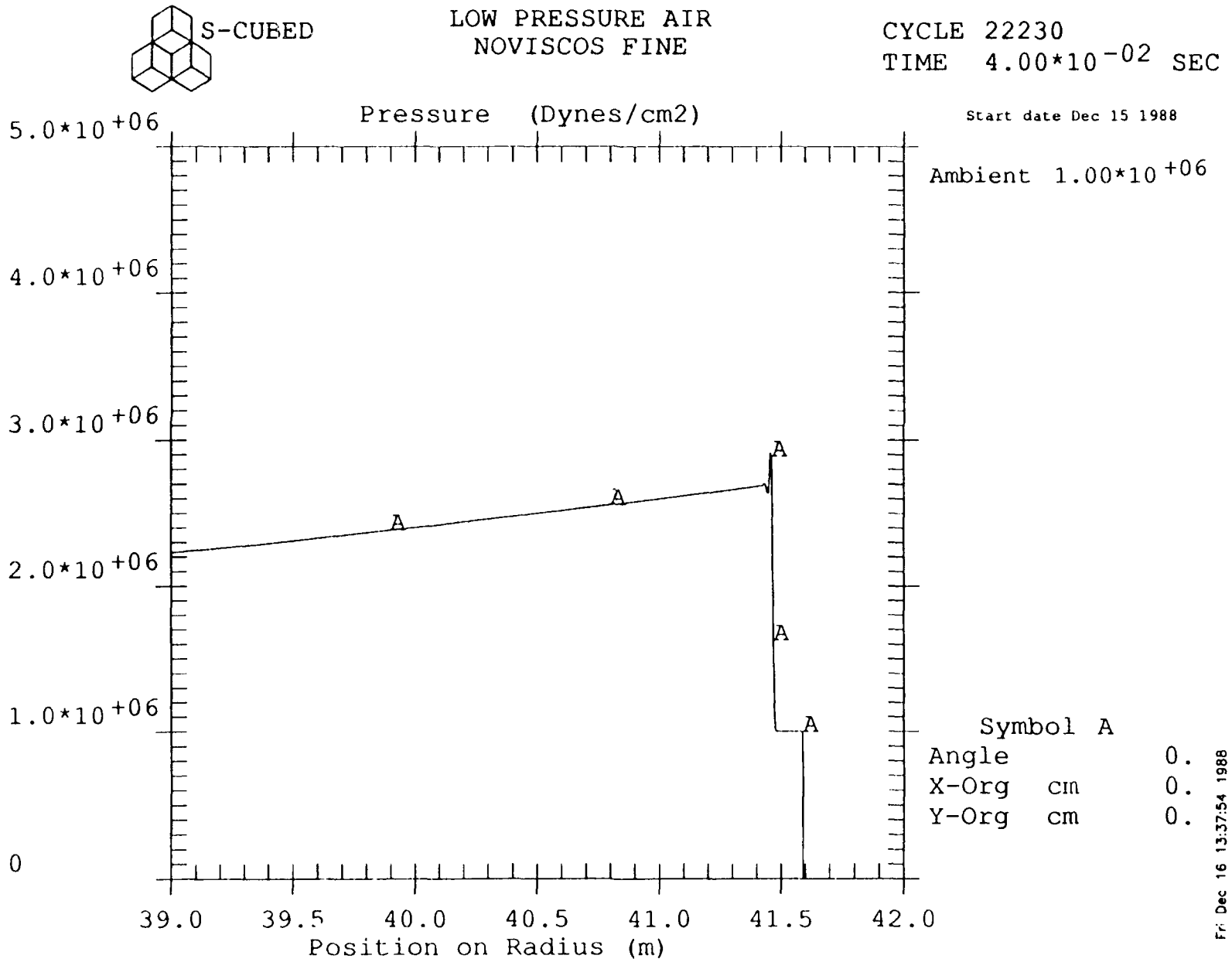

S-CUBED
LOW PRESSURE AIR
NO VISCOSITY COARSE ZONIs
CYCLE 8247
TIME 4.00*10-01 SEC
Start date Jan 3 1989
Resultant Velocity (cm/sec)
5.0*10+03
4.0*10+03
3.0*10+03
2.0*10+03
1.0*10+03
0
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:06:16 1989

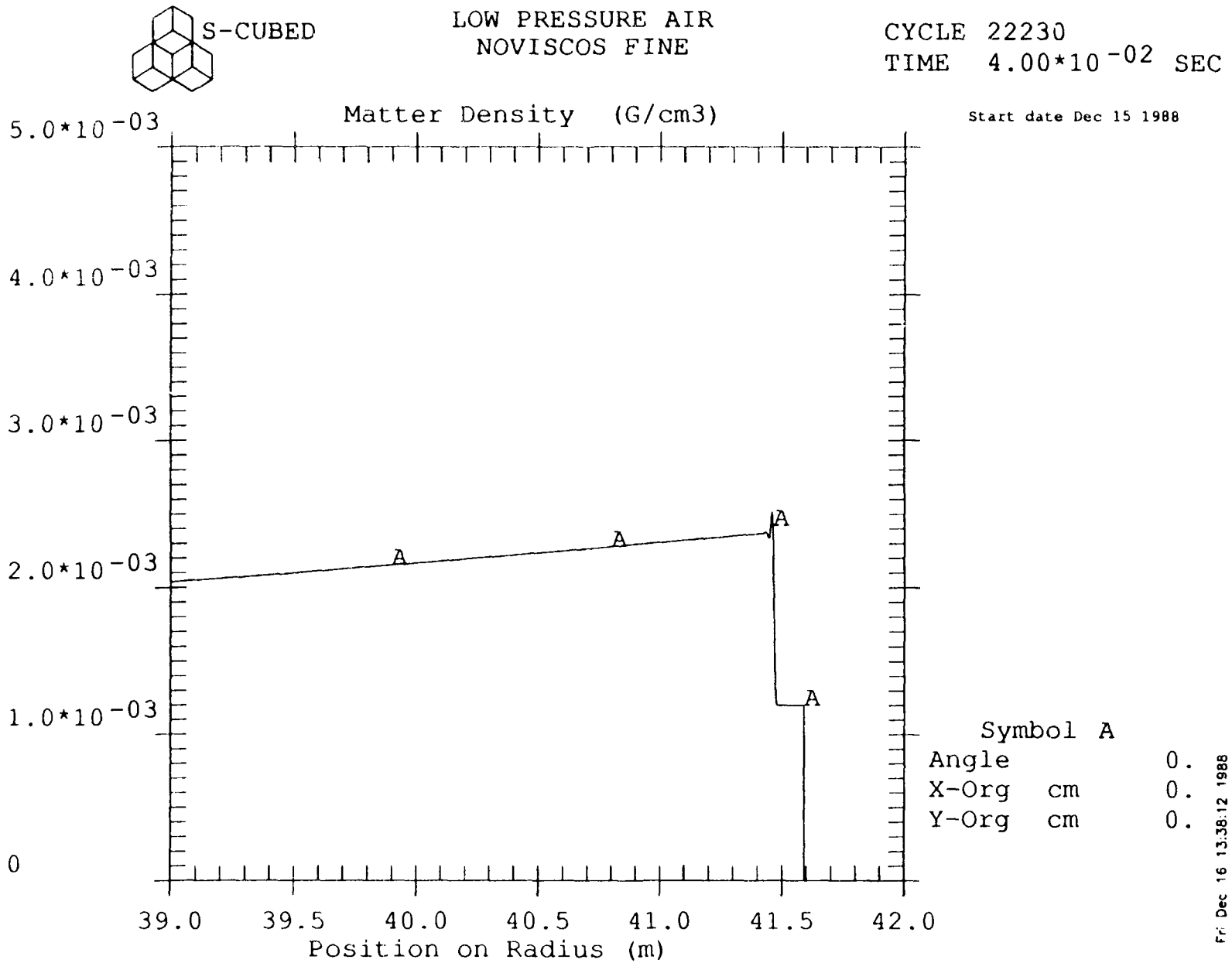
APPENDIX H
STANDARD STREAK
LOW PRESSURE, FINE ZONING

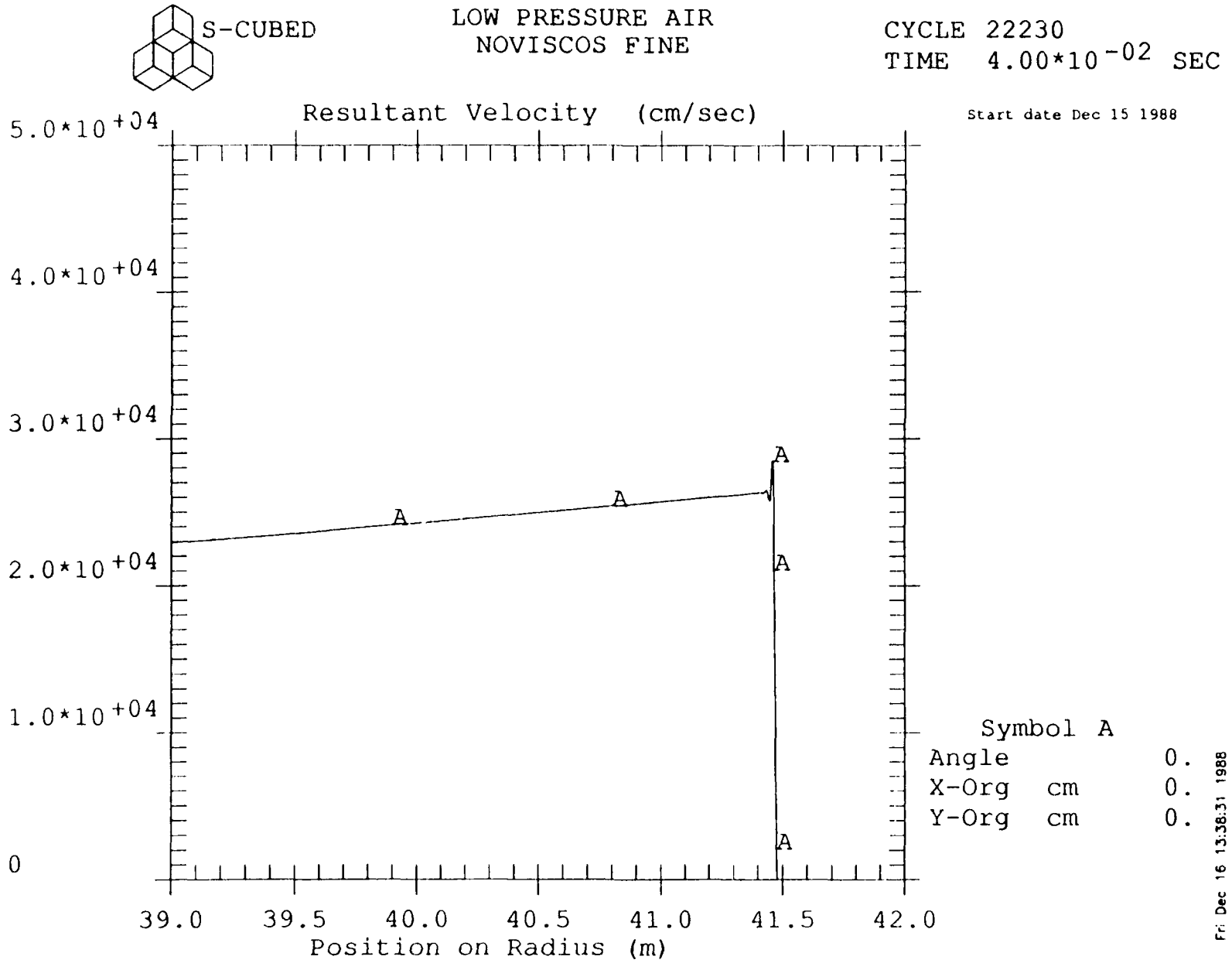

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 11660
TIME 1.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Dec 15 1988
Ambient 1.00*10 +06
1.0*10 +07
9.0*10 +06
8.0*10 +06
7.0*10 +06
6.0*10 +06
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fr Dec 16 13:25:04 1988

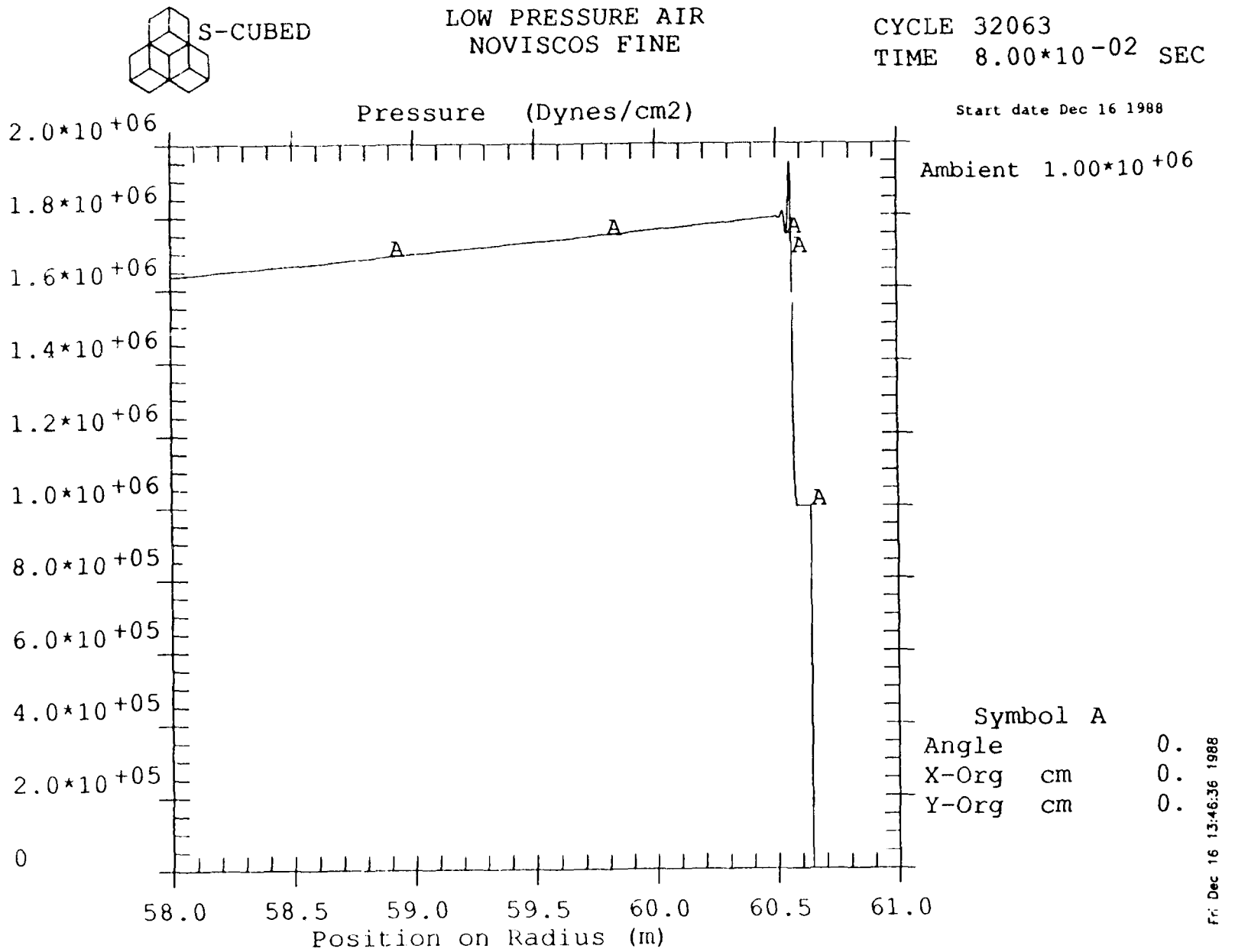

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 11660
TIME 1.00*10-02 SEC
Start date Dec 15 1988
Matter Density (G/cm3)
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fr Dec 16 13:25:14 1988

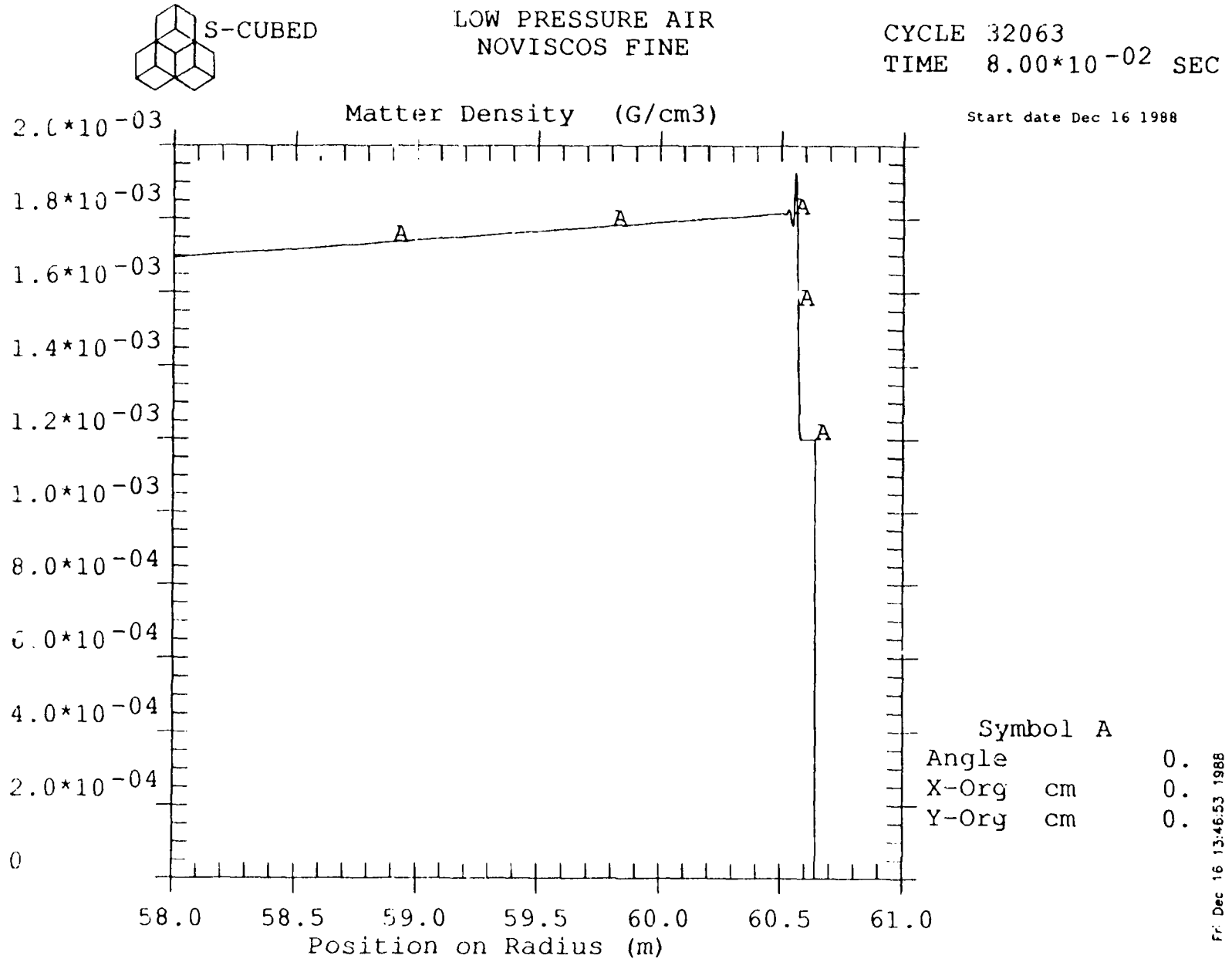

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 11660
TIME 1.00*10 -02 SEC
Resultant Velocity (cm/sec)
Start date Dec 15 1988
1.0*10 +05
9.0*10 +04
8.0*10 +04
7.0*10 +04
6.0*10 +04
5.0*10 +04
4.0*10 +04
3.0*10 +04
2.0*10 +04
1.0*10 +04
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fr. Dec 16 13:25:24 1988

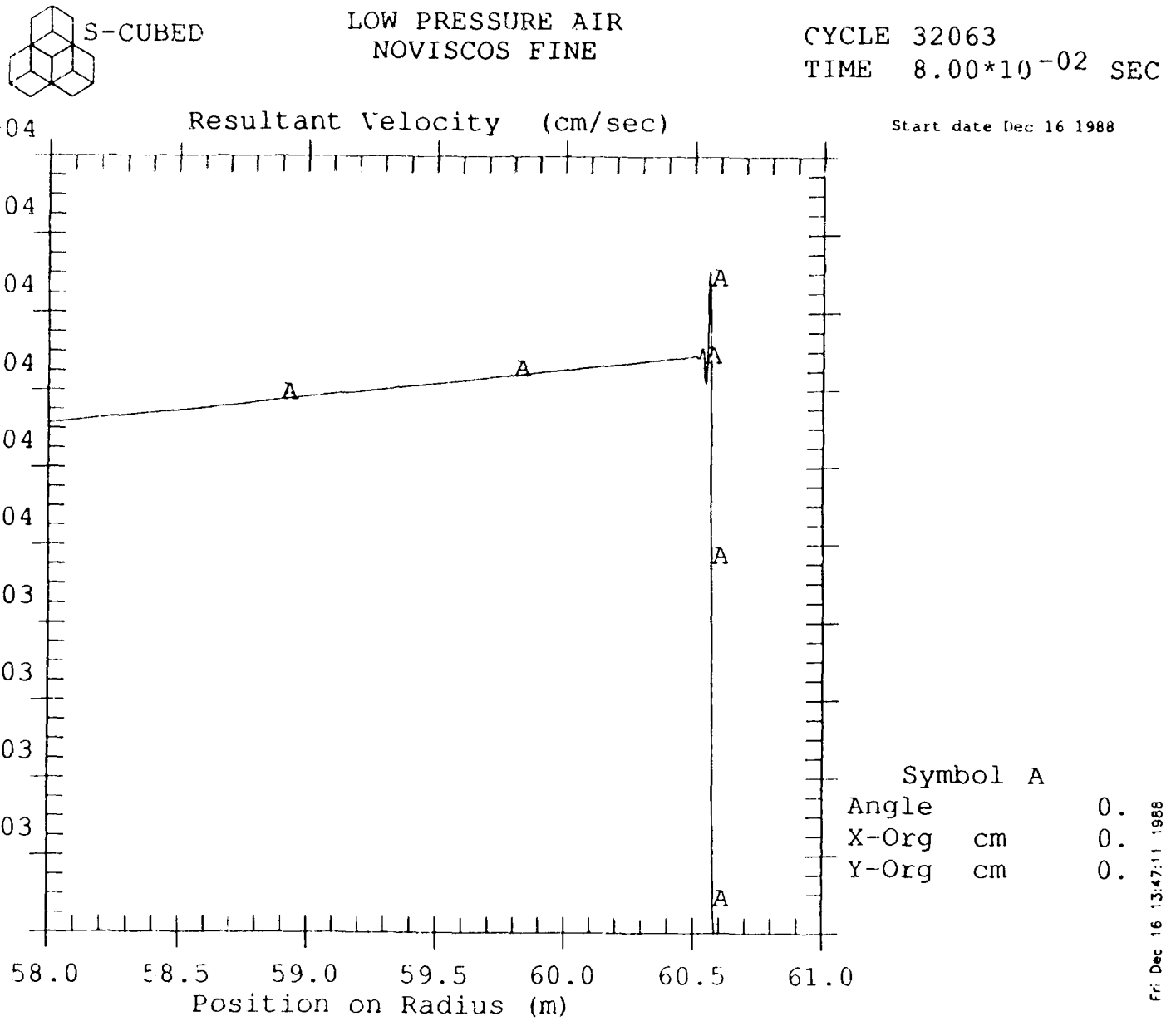

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 22230
TIME 4.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Dec 15 1988
Ambient 1.00*10 +06
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
A
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Fri Dec 16 13:37:54 1988


S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 22230
TIME 4.00*10 -02 SEC
Start date Dec 15 1988
Matter Density (G/cm3)
5.0*10 -03
4.0*10 -03
3.0*10 -03
2.0*10 -03
1.0*10 -03
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Fri Dec 16 13:38:12 1988

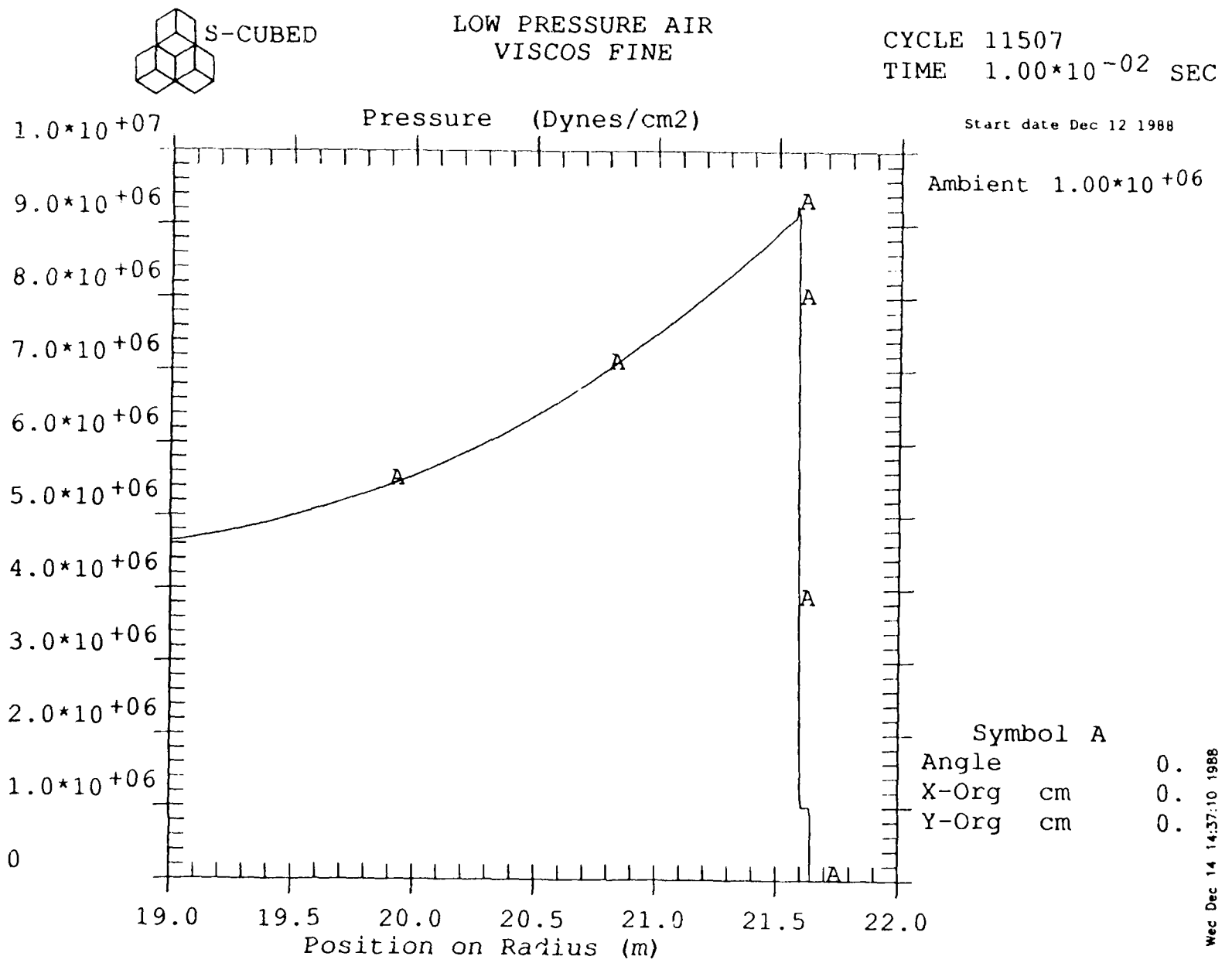

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 22230
TIME 4.00*10-02 SEC
Start date Dec 15 1988
Resultant Velocity (cm/sec)
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 16 13:38:31 1988

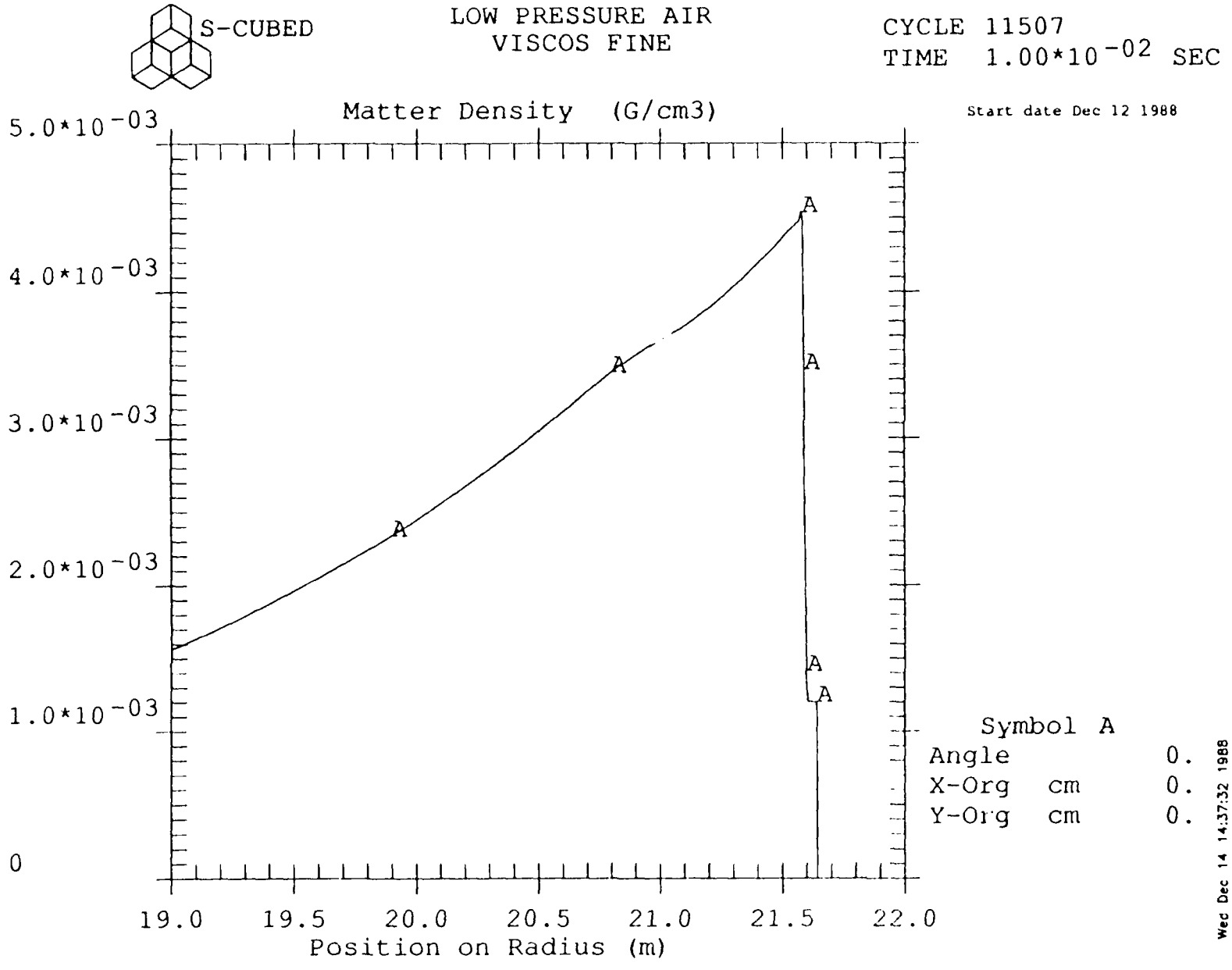

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 32063
TIME 8.00*10-02 SEC
Start date Dec 16 1988
Pressure (Dynes/cm2)
2.0*10+06
1.8*10+06
1.6*10+06
1.4*10+06
1.2*10+06
1.0*10+06
8.0*10+05
6.0*10+05
4.0*10+05
2.0*10+05
0
Ambient 1.00*10+06
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 16 13:46:36 1988

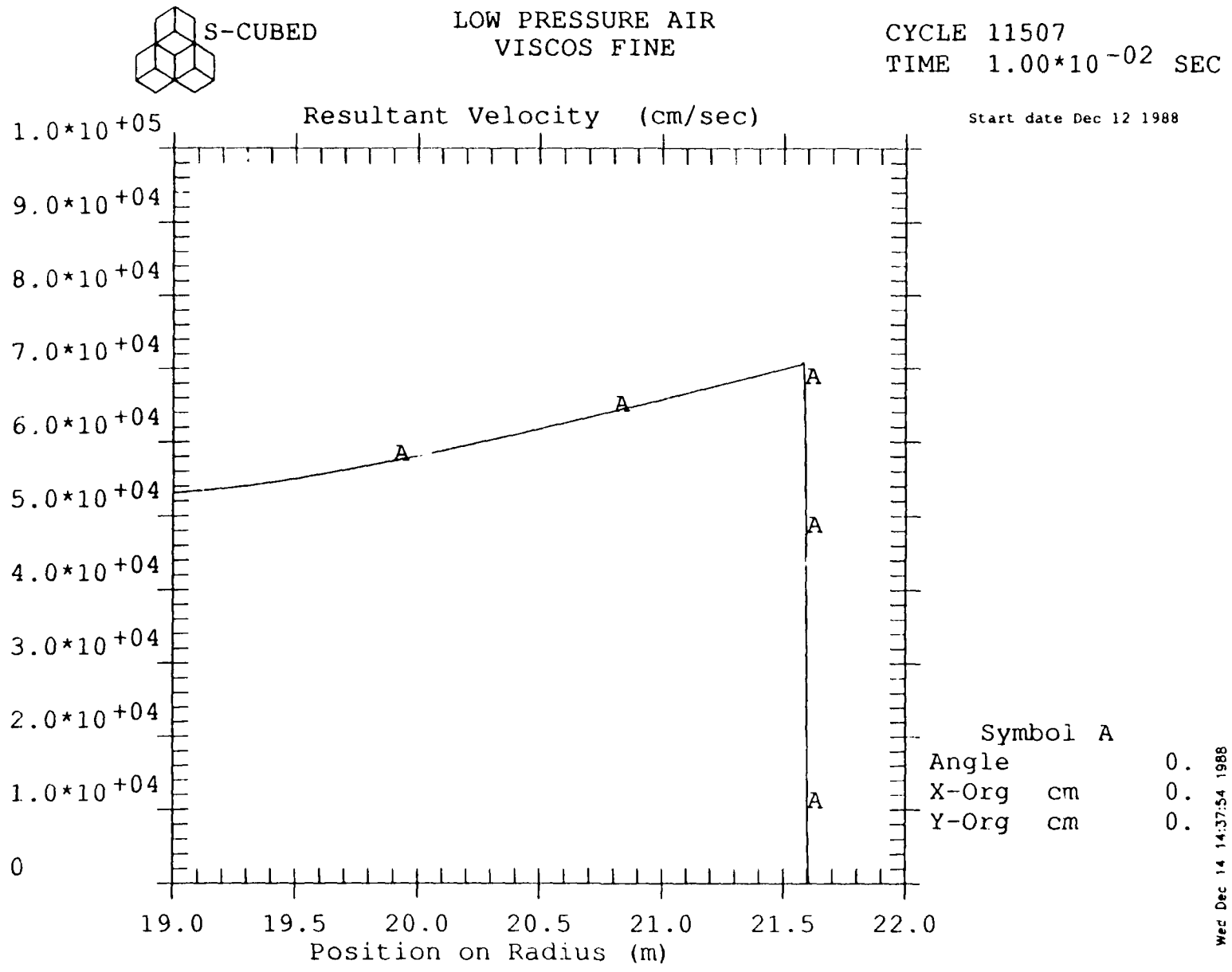

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 32063
TIME 8.00*10 -02 SEC
Start date Dec 16 1988
Matter Density (G/cm3)
2.0*10 -03
1.8*10 -03
1.6*10 -03
1.4*10 -03
1.2*10 -03
1.0*10 -03
8.0*10 -04
6.0*10 -04
4.0*10 -04
2.0*10 -04
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 16 13:46:53 1988

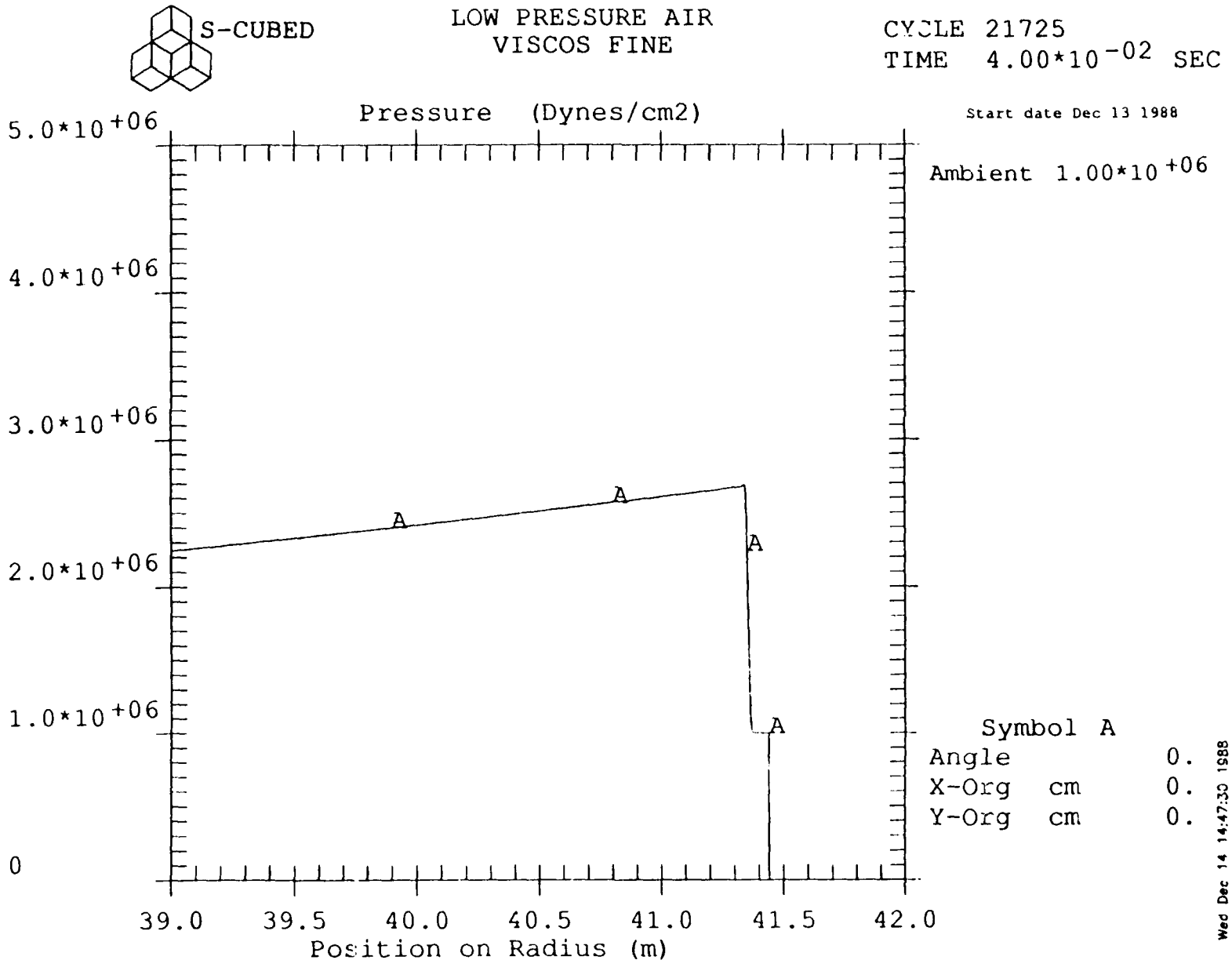

S-CUBED
LOW PRESSURE AIR
NOVISCOS FINE
CYCLE 32063
TIME 8.00*10-02 SEC
Start date Dec 16 1988
Resultant Velocity (cm/sec)
2.0*10+04
1.8*10+04
1.6*10+04
1.4*10+04
1.2*10+04
1.0*10+04
8.0*10+03
6.0*10+03
4.0*10+03
2.0*10+03
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Fri Dec 16 13:47:11 1988

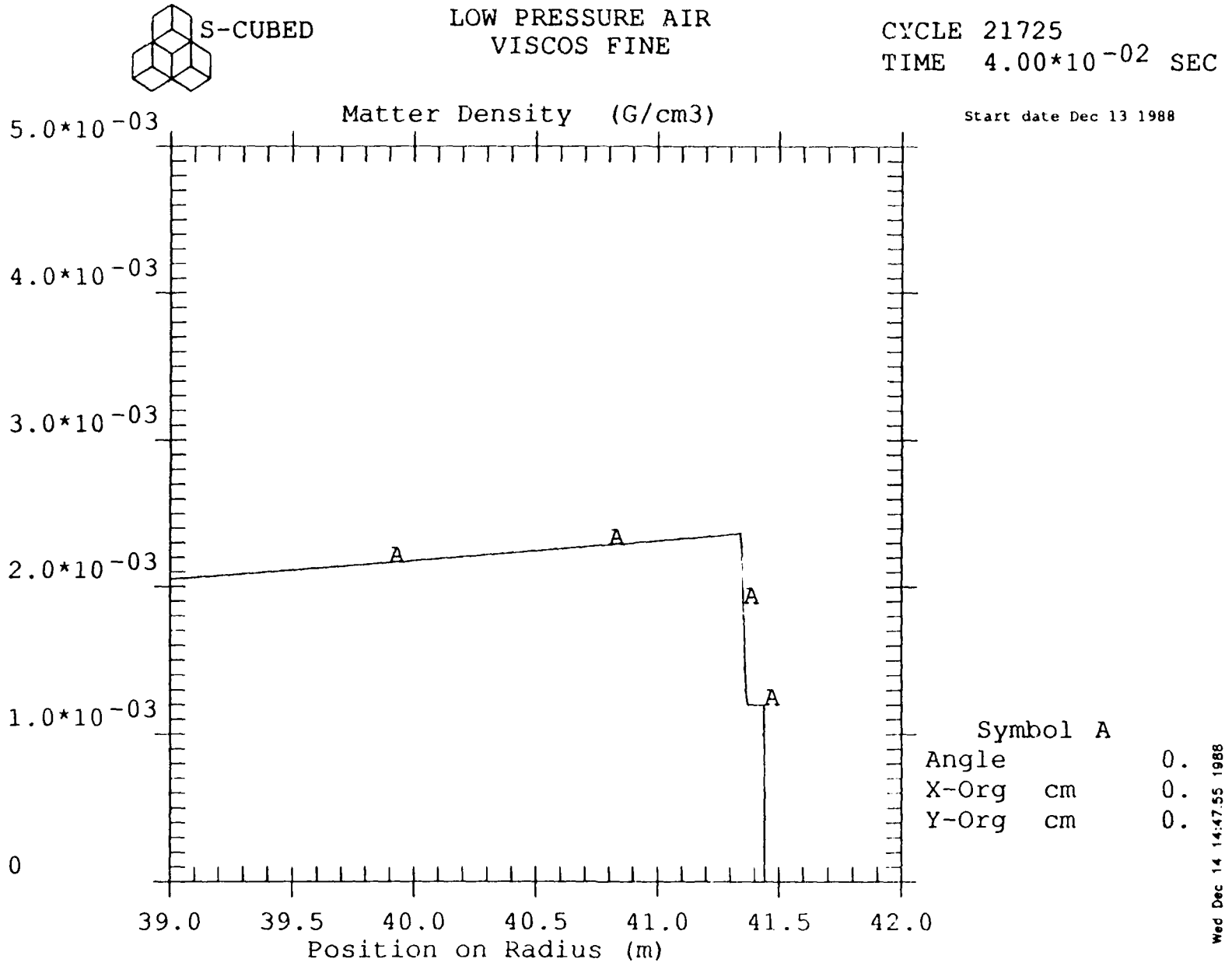
APPENDIX I
STREAK WITH $C_L = 0.5$
LOW PRESSURE, FINE ZONING

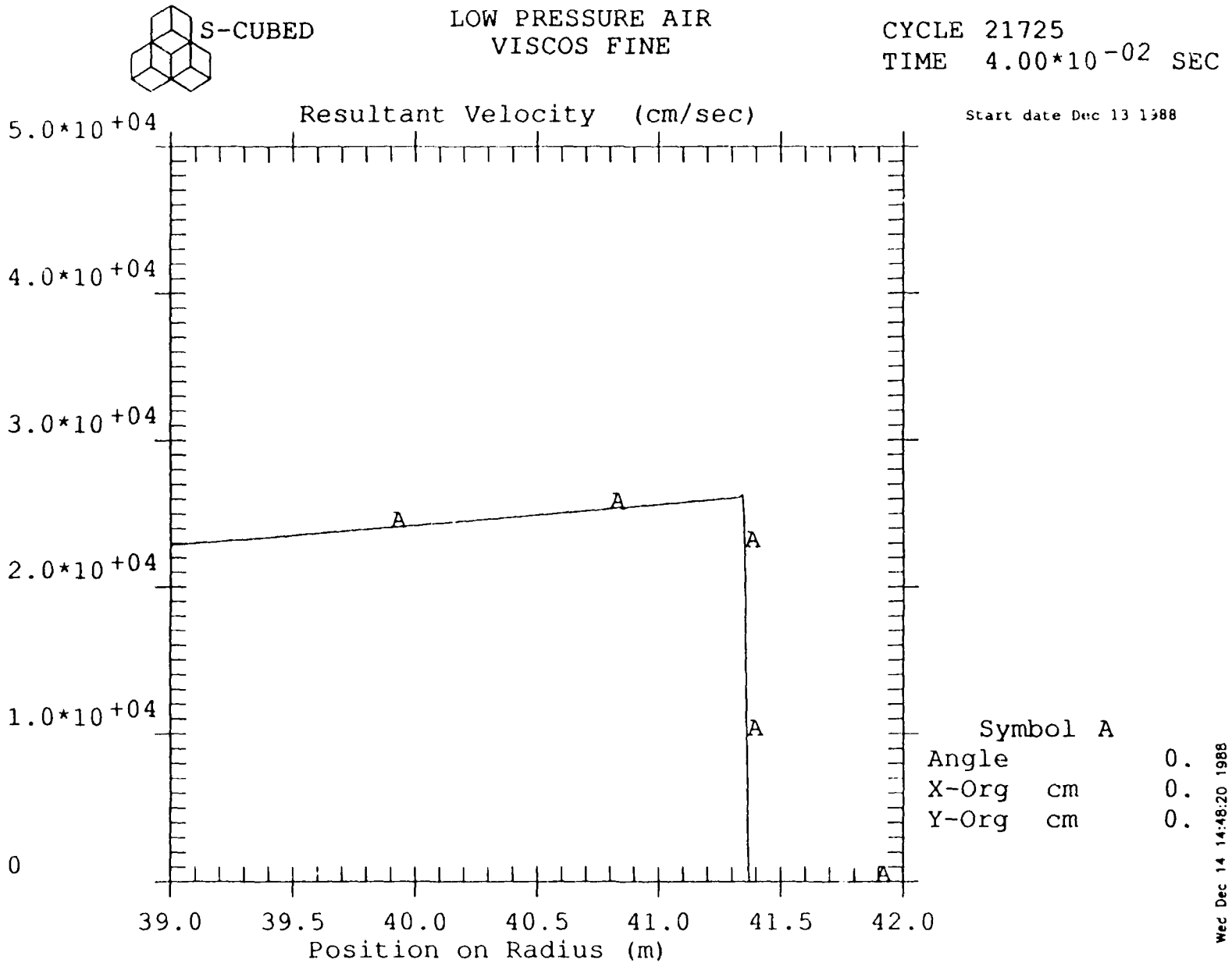

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 11507
TIME 1.00*10^-02 SEC
Pressure (Dynes/cm2)
Start date Dec 12 1988
Ambient 1.00*10^+06
1.0*10^+07
9.0*10^+06
8.0*10^+06
7.0*10^+06
6.0*10^+06
5.0*10^+06
4.0*10^+06
3.0*10^+06
2.0*10^+06
1.0*10^+06
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 14:37:10 1988

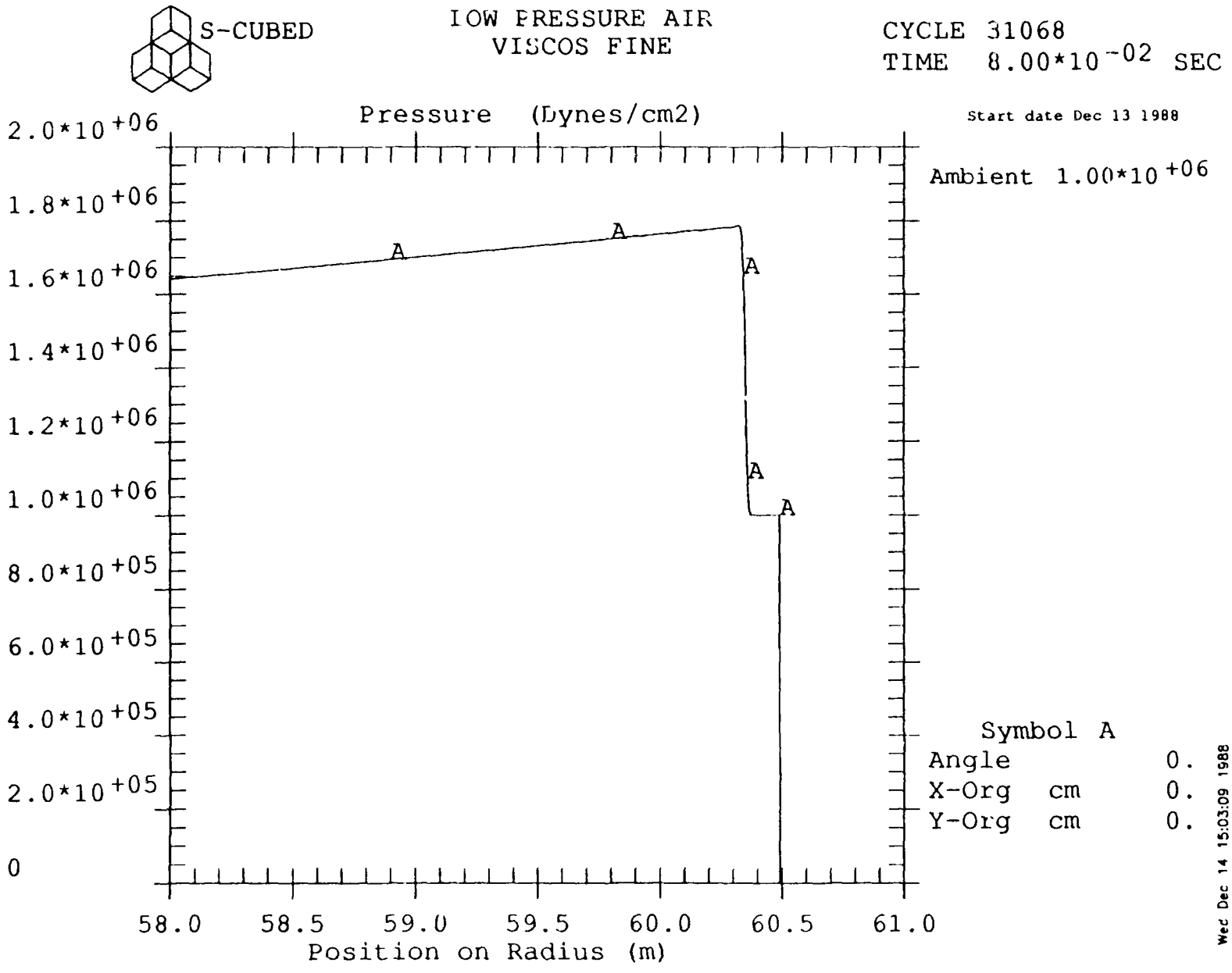

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 11507
TIME 1.00*10-02 SEC
Start date Dec 12 1988
Matter Density (G/cm3)
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 14:37:32 1988

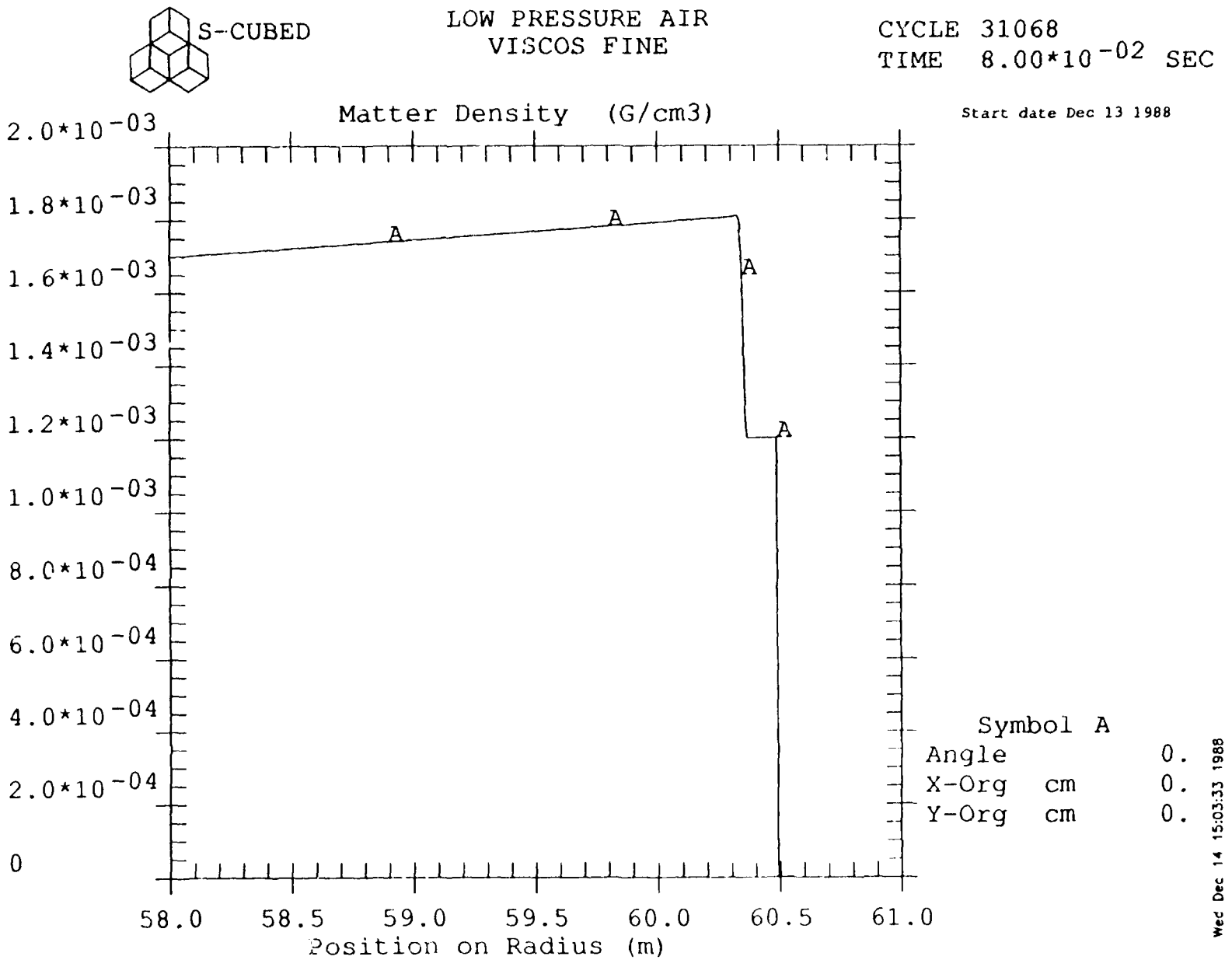

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 11507
TIME 1.00*10^-02 SEC
Start date Dec 12 1988
Resultant Velocity (cm/sec)
1.0*10^+05
9.0*10^+04
8.0*10^+04
7.0*10^+04
6.0*10^+04
5.0*10^+04
4.0*10^+04
3.0*10^+04
2.0*10^+04
1.0*10^+04
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 14:37:54 1988

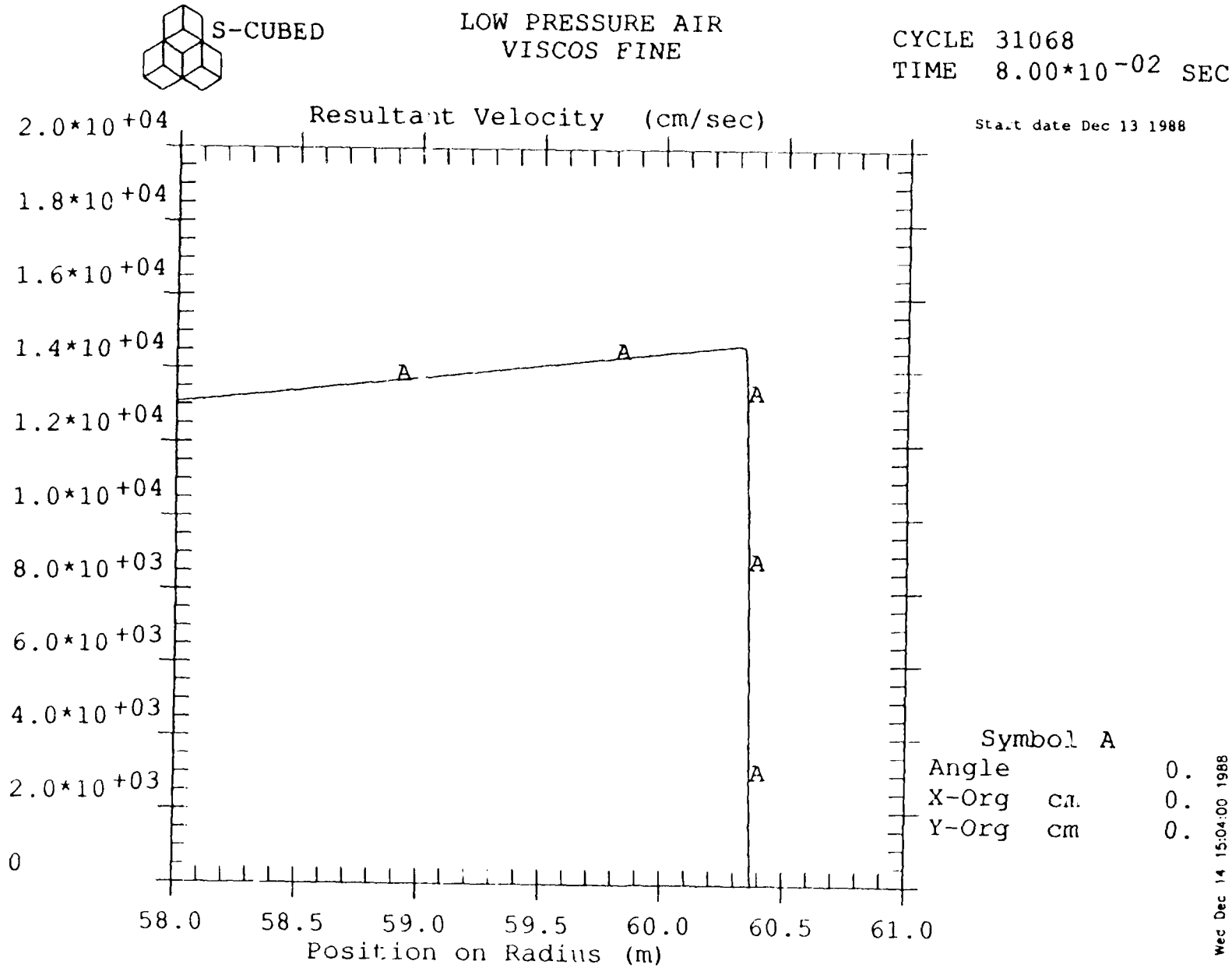

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 21725
TIME 4.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Dec 13 1988
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
Ambient 1.00*10 +06
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Wed Dec 14 14:47:30 1988


S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 21725
TIME 4.00*10-02 SEC
Start date Dec 13 1988
Matter Density (G/cm3)
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
A
A
A
A
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 14:47:55 1988

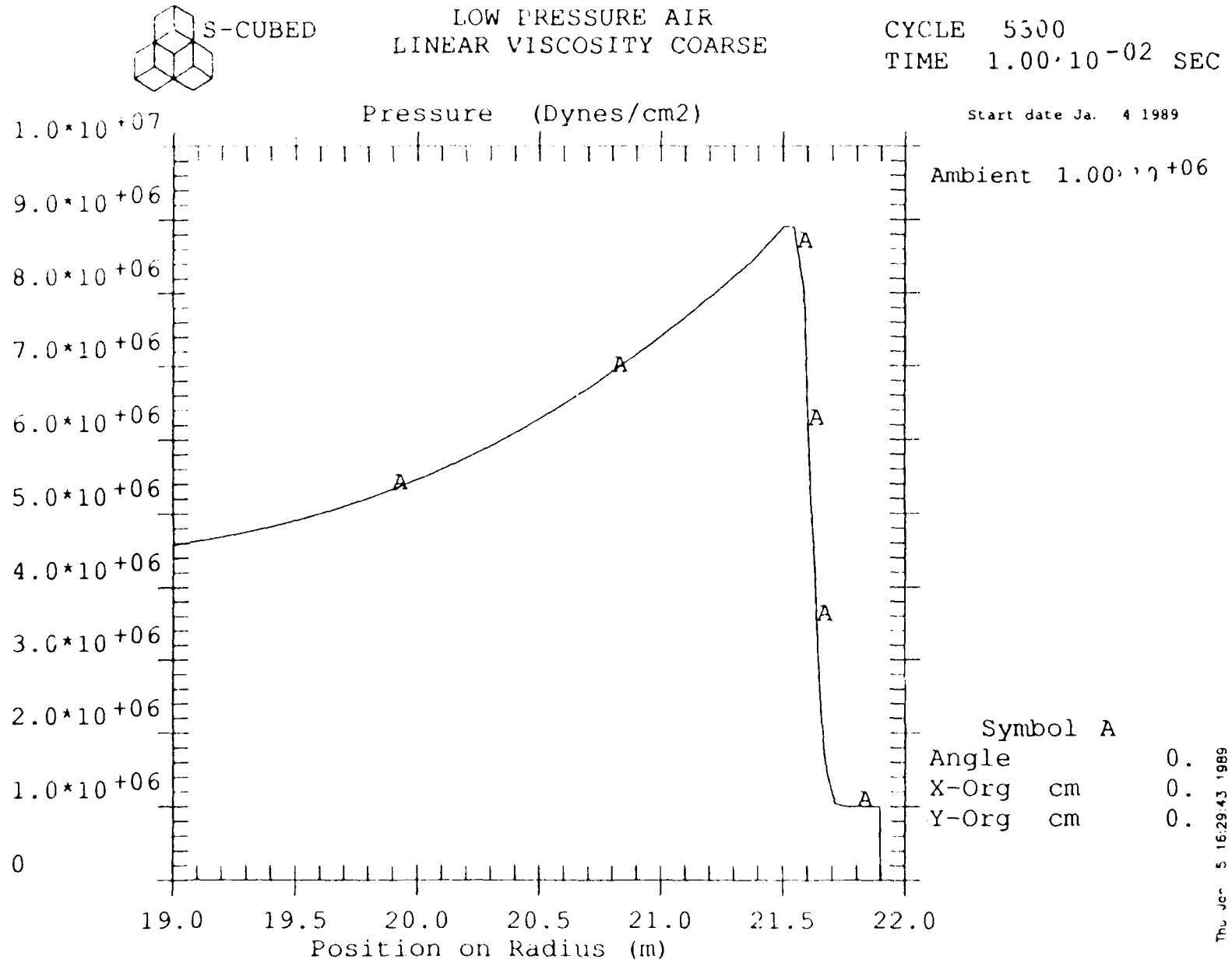

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 21725
TIME 4.00*10 -02 SEC
Resultant Velocity (cm/sec)
Start date Dec 13 1988
5.0*10 +04
4.0*10 +04
3.0*10 +04
2.0*10 +04
1.0*10 +04
0
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 14:48:20 1988

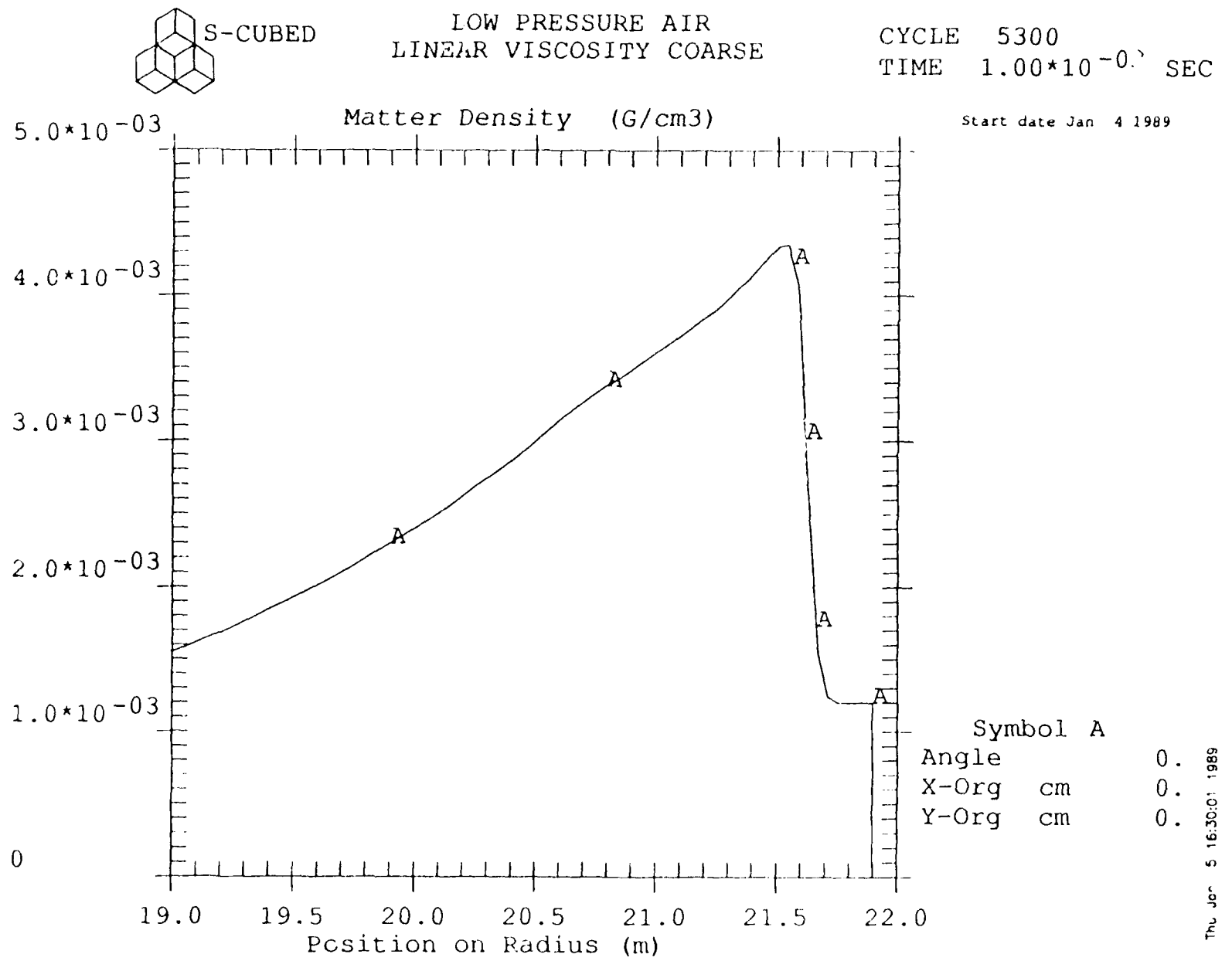

S-CUBED
IOW PRESSURE AIR
VISCOS FINE
CYCLE 31068
TIME 8.00*10^-02 SEC
Pressure (Dynes/cm2)
Start date Dec 13 1988
Ambient 1.00*10^+06
2.0*10^+06
1.8*10^+06
1.6*10^+06
1.4*10^+06
1.2*10^+06
1.0*10^+06
8.0*10^+05
6.0*10^+05
4.0*10^+05
2.0*10^+05
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 15:03:09 1988

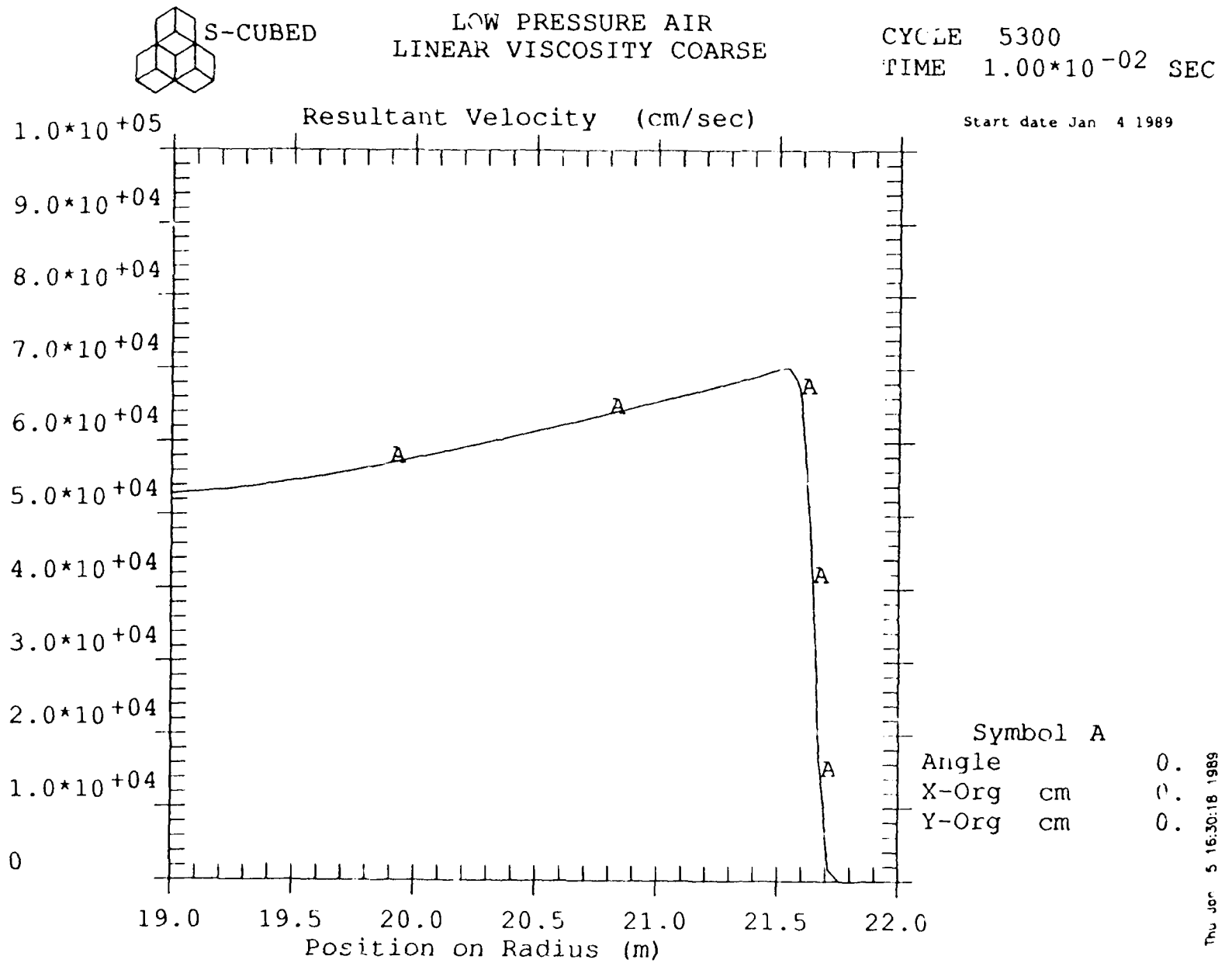

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 31068
TIME 8.00*10-02 SEC
Start date Dec 13 1988
Matter Density (G/cm3)
2.0*10-03
1.8*10-03
1.6*10-03
1.4*10-03
1.2*10-03
1.0*10-03
8.0*10-04
6.0*10-04
4.0*10-04
2.0*10-04
0
A
A
A
A
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 15:03:33 1988

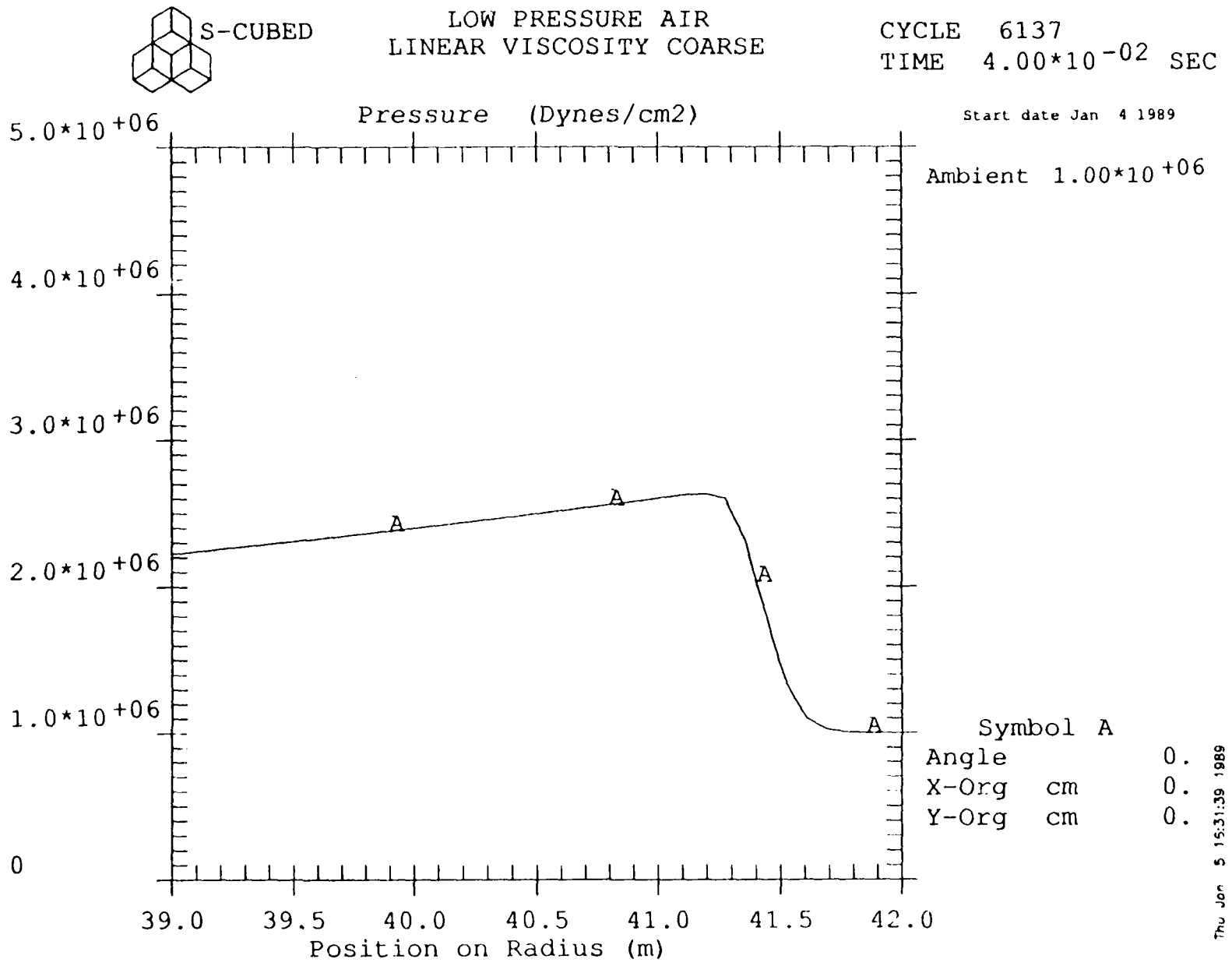

S-CUBED
LOW PRESSURE AIR
VISCOS FINE
CYCLE 31068
TIME 8.00*10-02 SEC
Start date Dec 13 1988
Resultant Velocity (cm/sec)
2.0*10+04
1.8*10+04
1.6*10+04
1.4*10+04
1.2*10+04
1.0*10+04
8.0*10+03
6.0*10+03
4.0*10+03
2.0*10+03
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Wed Dec 14 15:04:00 1988

APPENDIX J
STREAK WITH $C_L = 0.5$
LOW PRESSURE, COARSE ZONING


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 5300
TIME 1.00·10-02 SEC
Pressure (Dynes/cm2)
Start date Ja. 4 1989
Ambient 1.00·10+06
1.0*10+07
9.0*10+06
8.0*10+06
7.0*10+06
6.0*10+06
5.0*10+06
4.0*10+06
3.0*10+06
2.0*10+06
1.0*10+06
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:29:43 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 5300
TIME 1.00*10^-0.
SEC
Start date Jan 4 1989
Matter Density (G/cm3)
5.0*10^-03
4.0*10^-03
3.0*10^-03
2.0*10^-03
1.0*10^-03
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:30:01 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 5300
TIME 1.00*10-02 SEC
Start date Jan 4 1989
Resultant Velocity (cm/sec)
1.0*10+05
9.0*10+04
8.0*10+04
7.0*10+04
6.0*10+04
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
19.0
19.5
20.0
20.5
21.0
21.5
22.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:30:18 1989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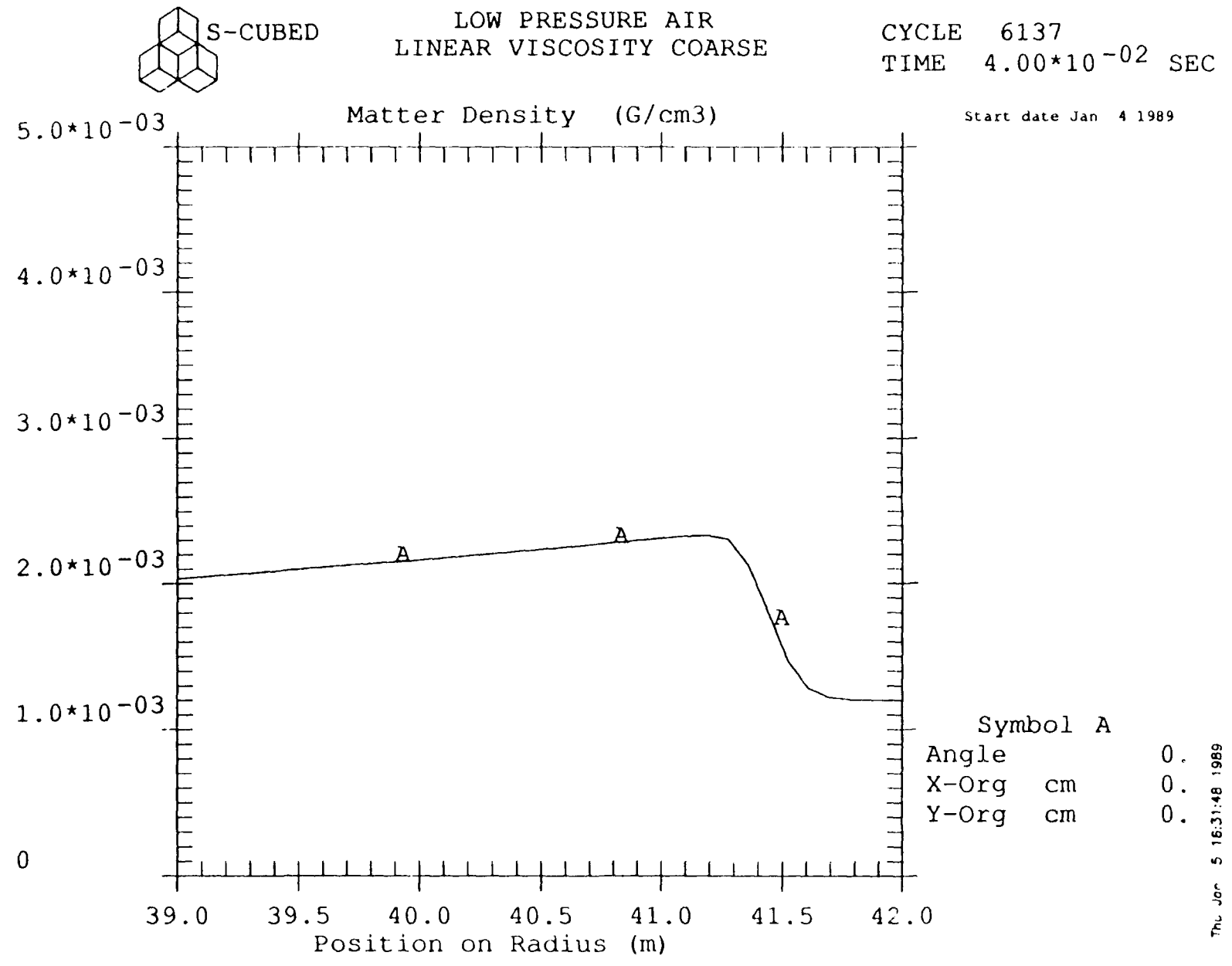
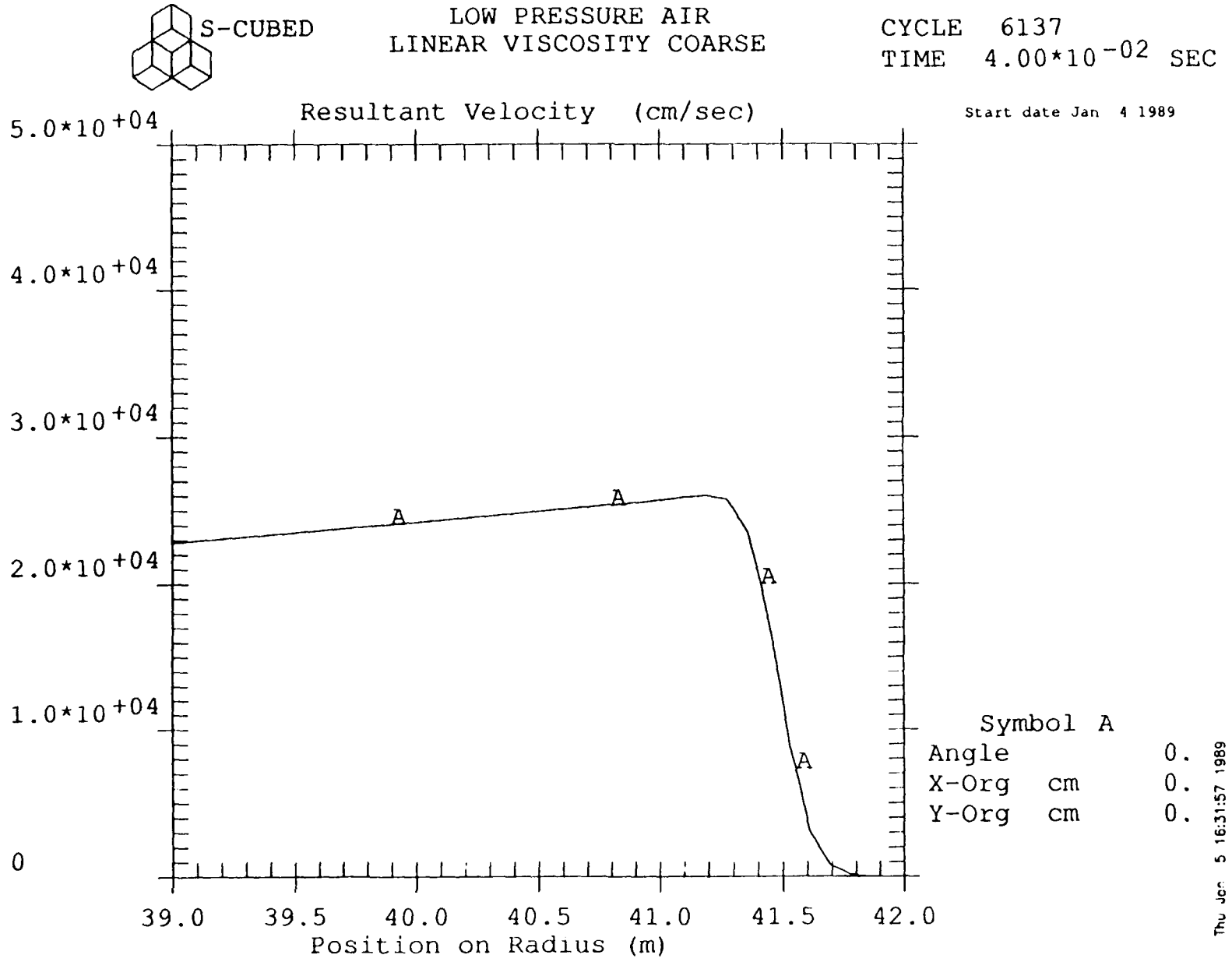
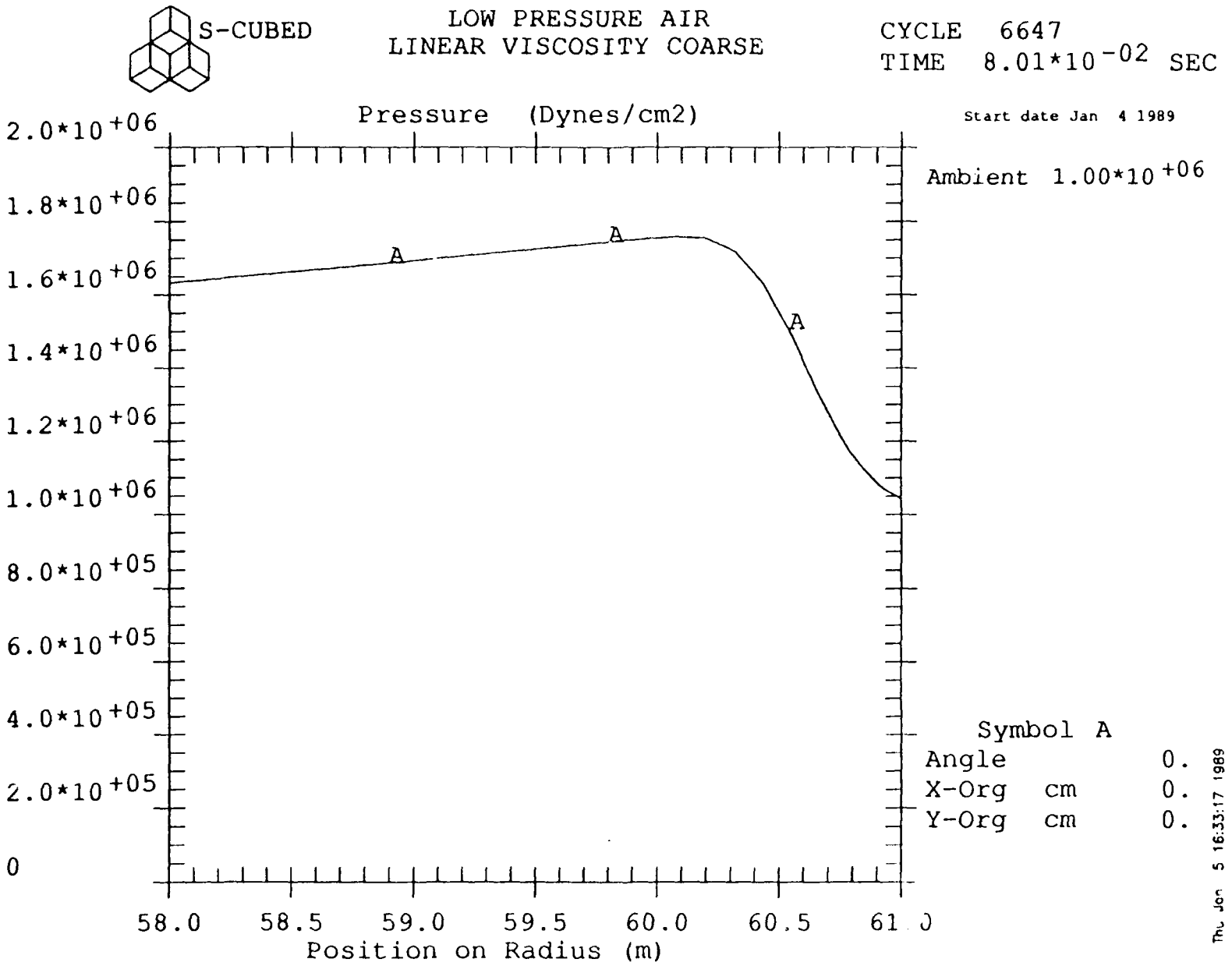
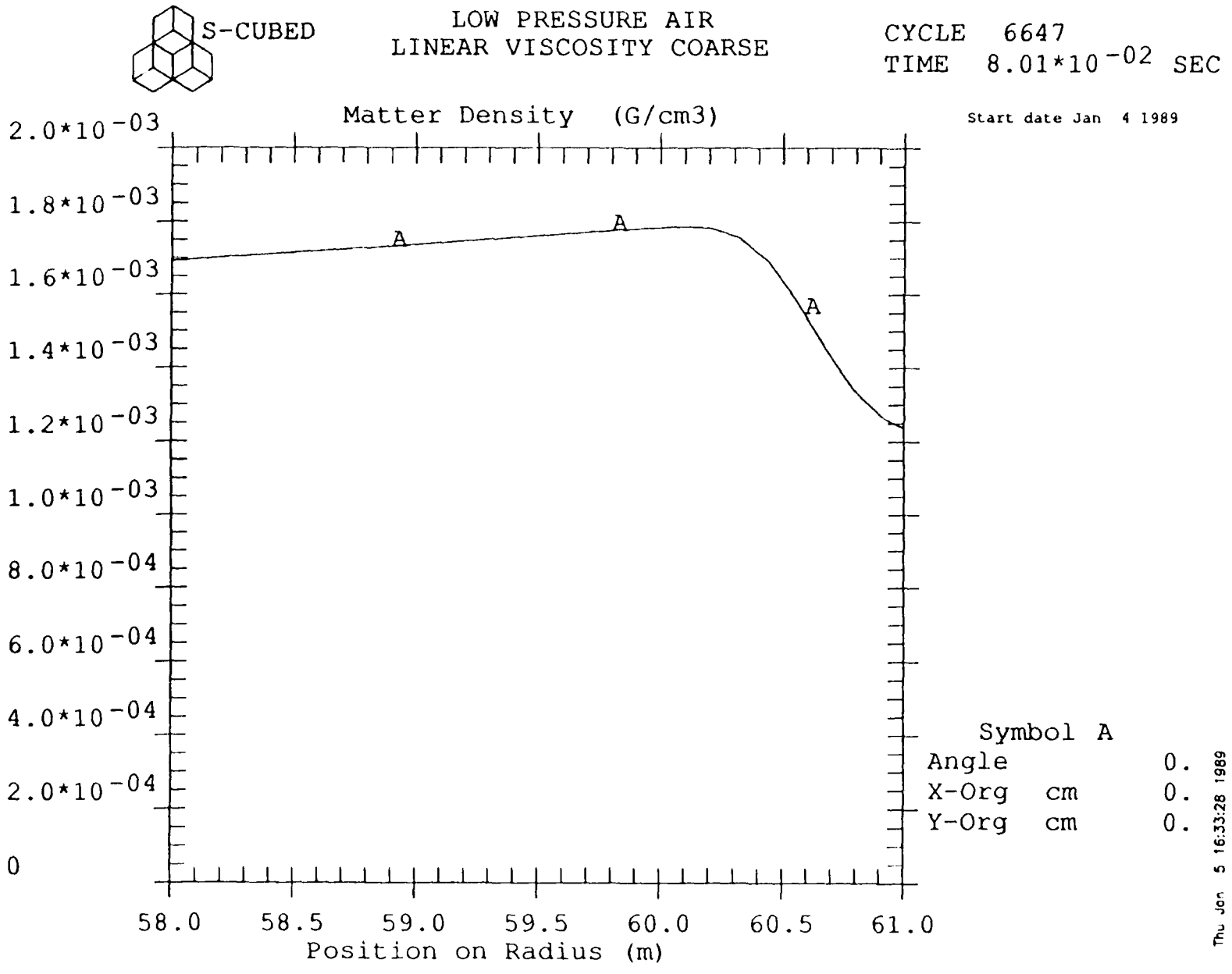
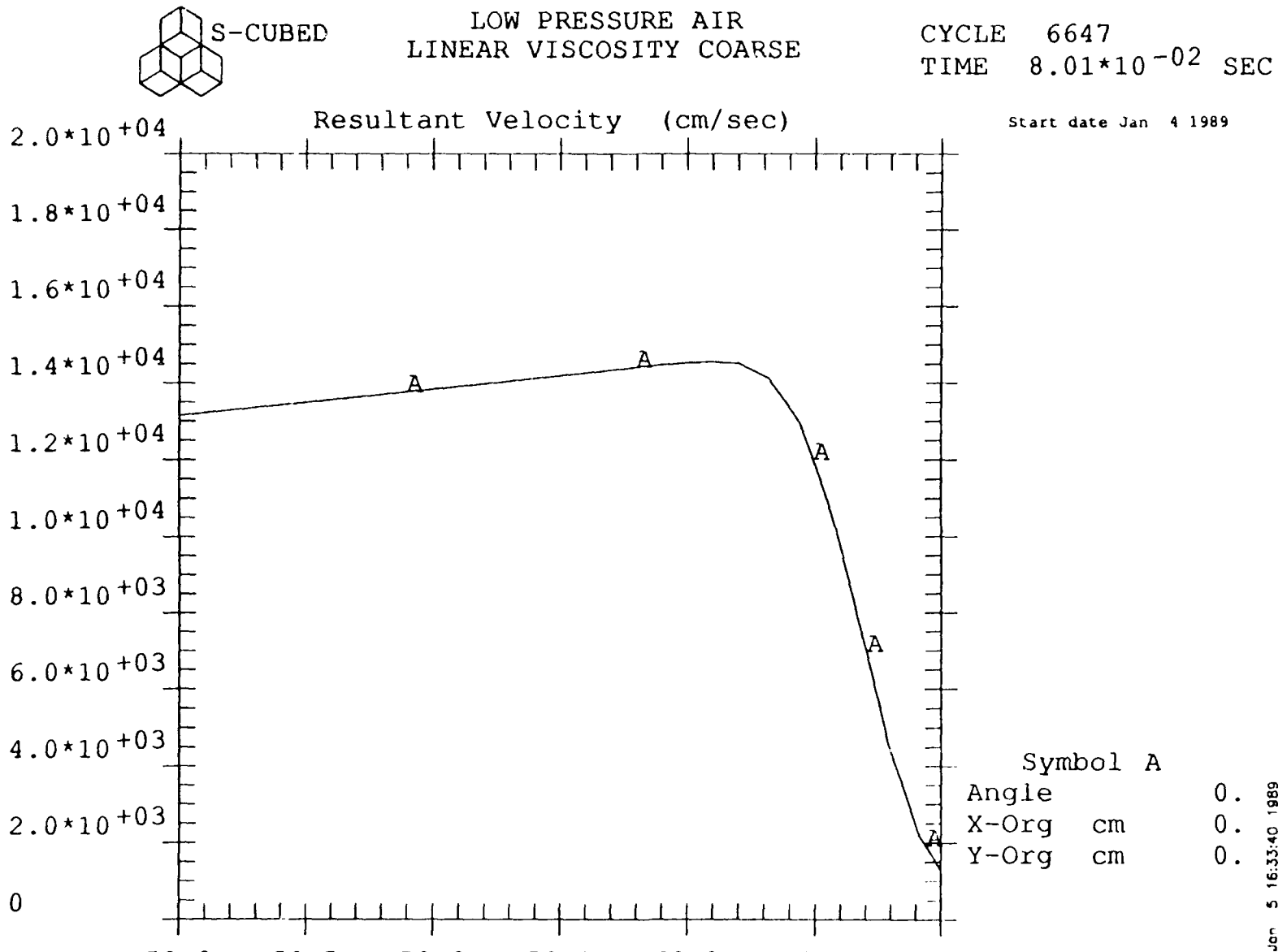
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6137
TIME 4.00*10 -02 SEC
Pressure (Dynes/cm2)
Start date Jan 4 1989
5.0*10 +06
4.0*10 +06
3.0*10 +06
2.0*10 +06
1.0*10 +06
0
Ambient 1.00*10 +06
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Thu Jan 5 15:31:39 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6137
TIME 4.00*10-02 SEC
Matter Density (G/cm3)
Start date Jan 4 1989
5.0*10-03
4.0*10-03
3.0*10-03
2.0*10-03
1.0*10-03
0
A
A
A
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:31:48 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6137
TIME 4.00*10-02 SEC
Resultant Velocity (cm/sec)
Start date Jan 4 1989
5.0*10+04
4.0*10+04
3.0*10+04
2.0*10+04
1.0*10+04
0
A
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
39.0
39.5
40.0
40.5
41.0
41.5
42.0
Position on Radius (m)
Thu Jan 5 16:31:57 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6647
TIME 8.01*10-02 SEC
Pressure (Dynes/cm2)
Start date Jan 4 1989
Ambient 1.00*10+06
2.0*10+06
1.8*10+06
1.6*10+06
1.4*10+06
1.2*10+06
1.0*10+06
8.0*10+05
6.0*10+05
4.0*10+05
2.0*10+05
0
A
A
A
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:33:17 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6647
TIME 8.01*10-02 SEC
Start date Jan 4 1989
Matter Density (G/cm3)
2.0*10-03
1.8*10-03
1.6*10-03
1.4*10-03
1.2*10-03
1.0*10-03
8.0*10-04
6.0*10-04
4.0*10-04
2.0*10-04
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
A
A
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:33:28 1989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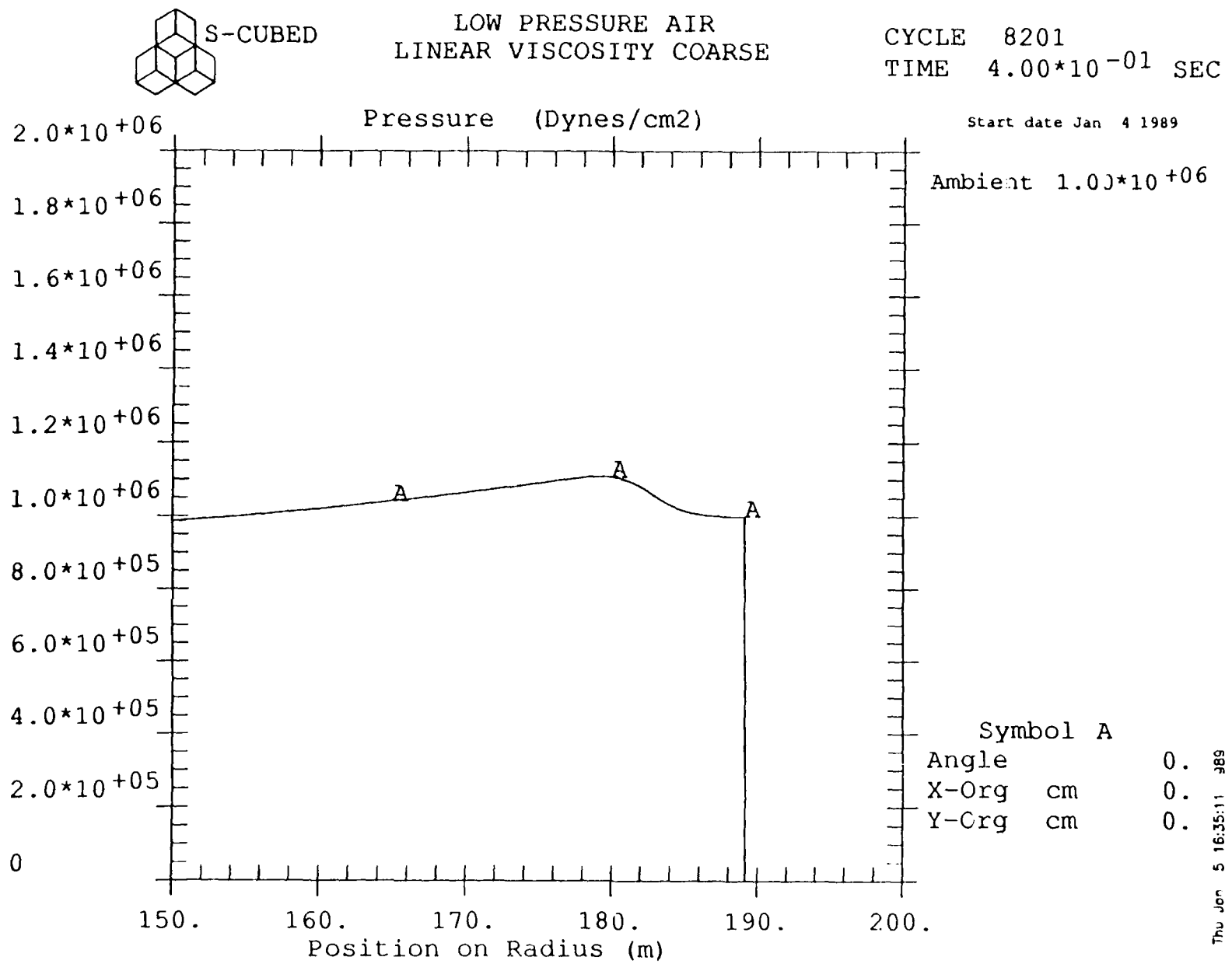
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 6647
TIME 8.01*10^-02 SEC
Resultant Velocity (cm/sec)
Start date Jan 4 1989
2.0*10^+04
1.8*10^+04
1.6*10^+04
1.4*10^+04
1.2*10^+04
1.0*10^+04
8.0*10^+03
6.0*10^+03
4.0*10^+03
2.0*10^+03
0
58.0
58.5
59.0
59.5
60.0
60.5
61.0
Position on Radius (m)
A
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:33:40 1989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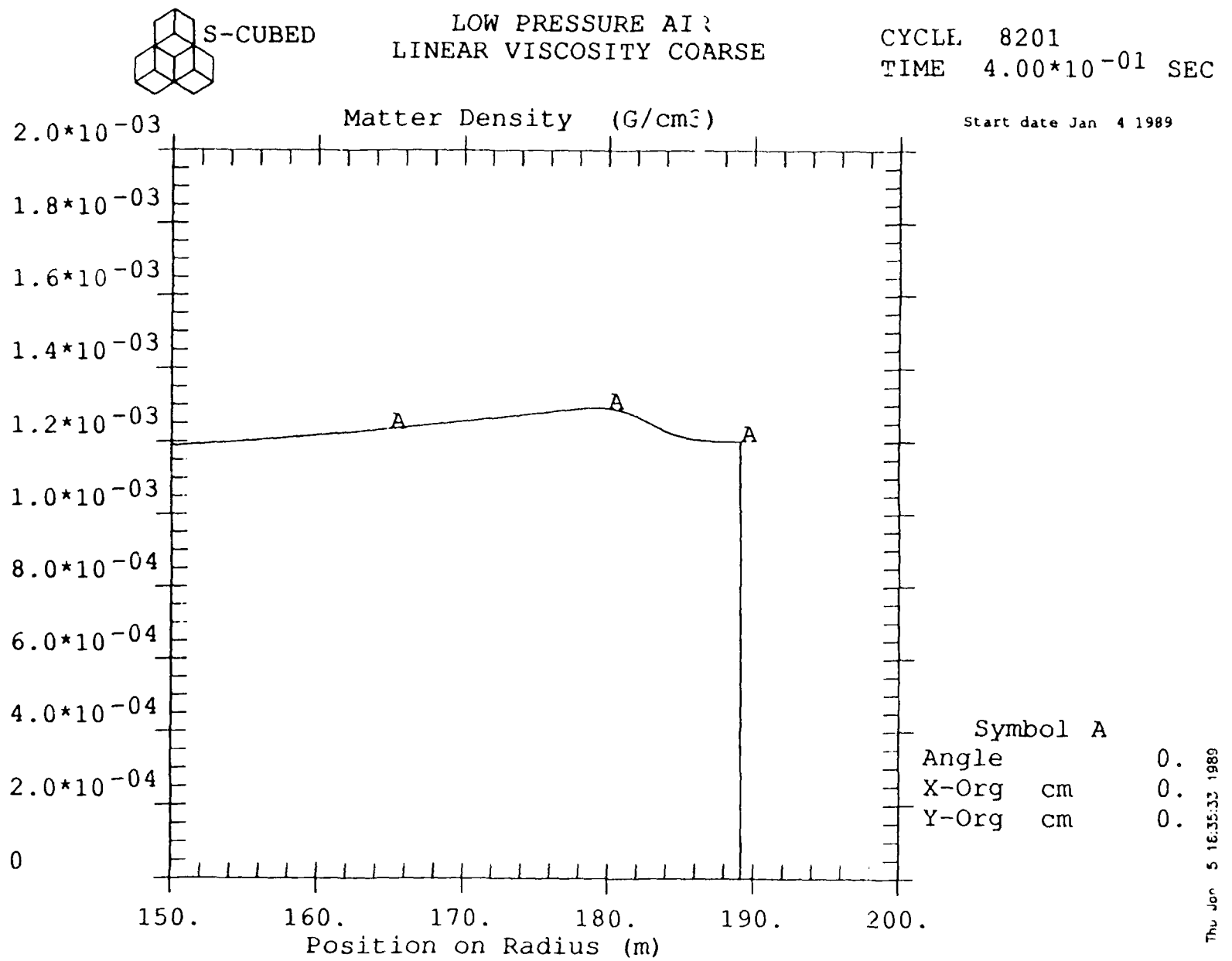
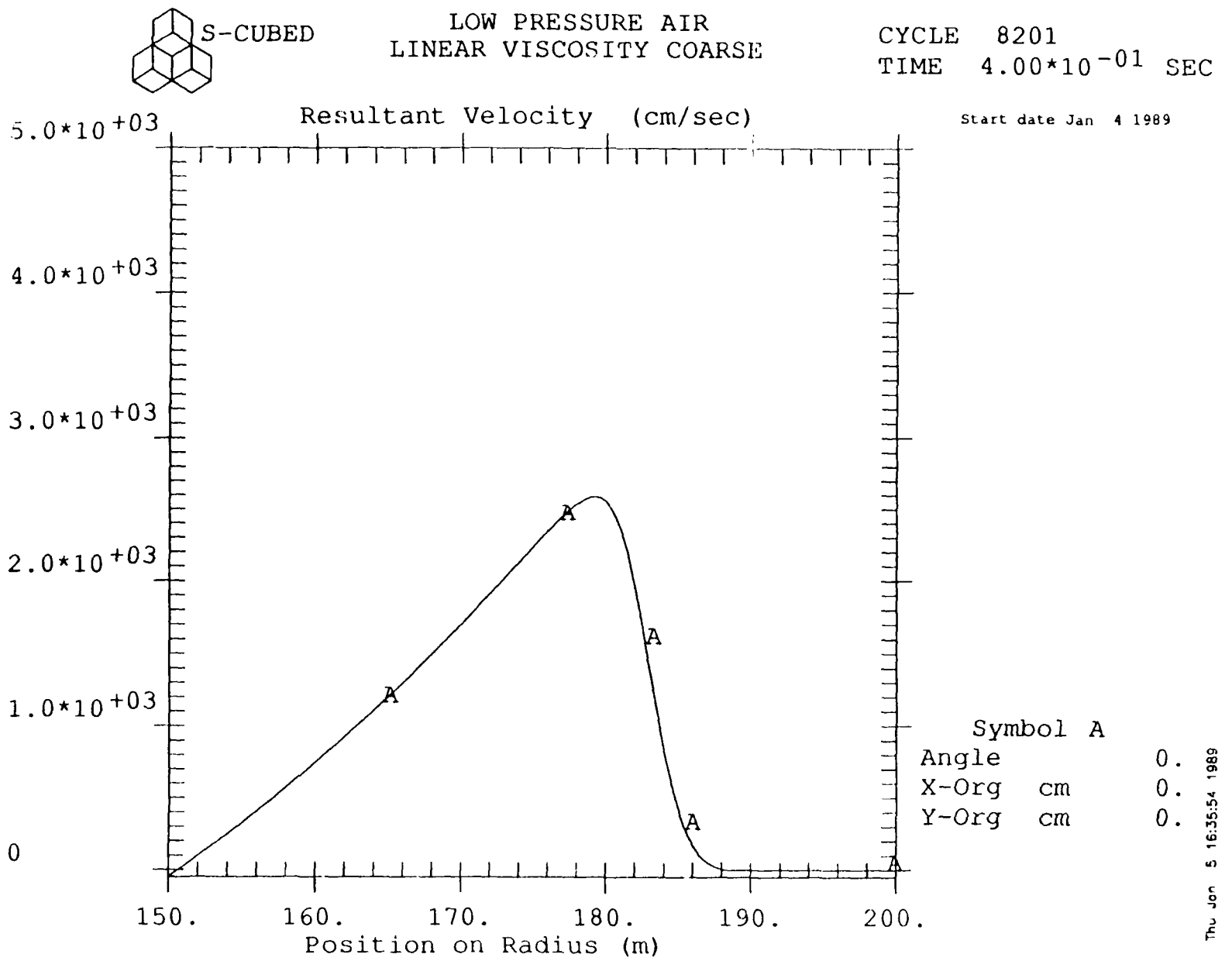
LINEAR VISCOSITY COARSE
CYCLE 8201
TIME 4.00*10 -01 SEC
Pressure (Dynes/cm2)
Start date Jan 4 1989
Ambient 1.00*10 +06
2.0*10 +06
1.8*10 +06
1.6*10 +06
1.4*10 +06
1.2*10 +06
1.0*10 +06
8.0*10 +05
6.0*10 +05
4.0*10 +05
2.0*10 +05
0
A
A
A
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:35:11 989


S-CUBED
LOW PRESSURE AI ?
LINEAR VISCOSITY COARSE
CYCLE 8201
TIME 4.00*10 -01 SEC
Matter Density (G/cm3)
Start date Jan 4 1989
2.0*10 -03
1.8*10 -03
1.6*10 -03
1.4*10 -03
1.2*10 -03
1.0*10 -03
8.0*10 -04
6.0*10 -04
4.0*10 -04
2.0*10 -04
0
A
A
A
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
Thu Jan 5 16:35:33 1989


S-CUBED
LOW PRESSURE AIR
LINEAR VISCOSITY COARSE
CYCLE 8201
TIME 4.00*10-01 SEC
Resultant Velocity (cm/sec)
Start date Jan 4 1989
5.0*10+03
4.0*10+03
3.0*10+03
2.0*10+03
1.0*10+03
0
150.
160.
170.
180.
190.
200.
Position on Radius (m)
Symbol A
Angle 0.
X-Org cm 0.
Y-Org cm 0.
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